

APPENDICES

(Note: Page numbers for PDF version may not be correct)

APPENDIX A: California Health and Safety Code, Article 9.5, Section 426.10	A1
APPENDIX B: VOCs That May Be Emitted From Building Materials and Cleaning Products	B1
APPENDIX C: Survey of Product Labeling Programs	C1
C1 United States: Carpet and Rug Institute's Carpet Labeling Program	C1
C2 United States: Hardwood Plywood and Veneer Association's and National Particleboard Association's Formaldehyde Labeling Program	C1
C3 Canada: Canadian Carpet Institute's (CCI) Carpet Labeling Program	C2
C4 Canada: "Ecologo" Program	C2
C5 Canada: Ontario Building Environmental Performance Assessment Criteria (BEPAC)	C2
C6 Germany: "Blue Angel" Environmental Labeling Program	C3
C7 Denmark: Labeling Program	C3
C8 Sweden: Flooring Material Labeling Program	C4
APPENDIX D: Technical Considerations During Building Bake-Outs	D1
APPENDIX E: Survey of Existing Guidelines for VOCs	E1
E1 Guidelines for TVOCs	E1
E1.1 European Guidelines on VOC Concentrations	E1
E1.2 Tucker's Classification of Low-Emitting Materials and Products	E1
E1.3 State of Washington's Requirements	E2
E2 Health Effects and Concentration Guidelines for Selected VOCs	E3
E2.1 Benzene	E3
E2.1.1 Sources	E3
E2.1.2 Exposure Route	E3
E2.1.3 Health Effects	E3
E2.2 Formaldehyde	E4
E2.2.1 Sources	E4
E2.2.2 Exposure Route	E4
E2.2.3 Health Effects	E4
E2.2.4 Guidelines for Formaldehyde	E5
E2.3 Methylene Chloride	E6
E2.3.1 Sources	E6
E2.3.2 Exposure Route	E6
E2.3.3 Health Effects	E6
E2.4 Styrene	E8
E2.4.1 Sources	E8
E2.4.2 Exposure Route	E8
E2.4.3 Health Effects	E8
E2.4.4 Guidelines for Styrene	E9
E2.5 Tetrachloroethylene	E9
E2.5.1 Sources	E9
E2.5.2 Exposure Route	E9
E2.5.3 Health Effects	E9
E2.6 Toluene	E10

E2.6.1 Sources	E10
E2.6.2 Exposure Route	E10
E2.6.3 Health Effects	E10
E2.6.4 Guidelines for Toluene	E11
E3 Sources of Information on Carcinogenicity and Reproductive Toxicity of VOCs	E12
E4 Sensory Effects of VOCs	E12
E4.1 Odor	E13
E4.2 Irritation	E14
APPENDIX F: Sample Language for Contract Documents	F1
APPENDIX G: Survey of Testing Methods for VOCs	G1
G1 American Society for Testing and Materials (ASTM)	G1
G2 Canadian General Standards Board (CGSB)	G1
G3 Commission of the European Community (CEC)	G1
G4 Nordic Countries: Nordtest Methods (NT)	G1
G5 Swedish National Testing and Research Institute and Swedish National Flooring Trade Association	G1
APPENDIX H: California Regulations for Architectural Coatings and Consumer Products	H1
H1 Architectural Coatings	H1
H2 Aerosol Paints	H2
H3 Consumer Products	H2
H4 References	H2
APPENDIX I: Estimating Indoor Concentrations From Emission Factors	I1
I1 Using Mass Balance Equations to Predict Indoor VOC Concentrations	I1
I1.1 A Simplified Mass Balance Equation for Calculating Indoor VOC Concentrations	I1
I2 Examples of Application of the Steady-State Equation	I2
I2.1 Example 1: Application of the Steady-State Equation in the Selection of a Carpet	I3
I2.2 Example 2: Application of the Steady-State Equation in the Selection of a Carpet Adhesive	I4
APPENDIX J: California's Minimum Ventilation Standard	J1
APPENDIX K: Information Resources	K1
K1 Building Management Associations	K1
K2 Professional and Standard-Setting Organizations	K2
K3 Product Manufacturers	K3
K4 Building Service Associations	K5
K5 Environmental Health Organizations	K6
K6 California Air Pollution Control Districts	K8
K7 California Public Agencies and Organizations That Can Assist People with Indoor Air Quality Concerns	K12
K8 Publications and Written Material on Indoor Air Quality	K12
K8.1 List of USEPA's publications	K12
K8.2 List of National Institute of Standards and Technology Publications	K13
K8.3 List of the CARB's publications	K13

K9 Irritation/Toxicity Information Sources	K15
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APPENDIX A: California Health and Safety Code, Article 9.5, Section 426.10

HEALTH AND SAFETY CODE

§ 426.10

ARTICLE 9.5 INDOOR ENVIRONMENTAL QUALITY

Section

426.10. Volatile organic compounds in newly constructed or remodeled office buildings; nonbinding guidelines.

§ 426.10. Volatile organic compounds in newly constructed or remodeled office buildings; nonbinding guidelines

(a) The state department through its Indoor Air Quality Program shall develop nonbinding guidelines for the reduction of exposure to volatile organic compounds (VOC) from construction materials in newly constructed or remodeled office buildings. At a minimum, the state department shall consider all of the following:

- (1) The type of building to which the guidelines shall apply.
- (2) The methodology for identifying indoor sources of VOC.
- (3) The bake-out procedures prior to occupancy for newly constructed buildings.
- (4) The procedures for VOC reduction during and after major remodeling of occupied buildings.

(5) The need to establish mandatory regulations rather than nonbinding guidelines for the procedures to reduce VOC exposure in newly constructed buildings and during the remodeling of buildings and, in addition, the need for regulation regarding the occupancy of a newly constructed building or a building undergoing remodeling where VOC reduction is to be a consideration.

(6) The need to establish an ad hoc group of building construction material manufacturers, builders, building owners and managers, organized labor, sheetmetal contractors, plumbing contractors, mechanical engineers, architects, and building inspectors to advise the state department on procedures and costs related to implementing the proposed guidelines.

(b) The state department shall develop and submit the nonbinding guidelines to the Legislature, and file copies with the Department of General Services and the State Building Standards Commission, by January 1, 1992.

(c) The guidelines developed by the state department pursuant to this section shall be nonbinding and voluntary, and shall therefore, be exempt from the procedures for adoption of regulations, including the review and approval by the Office of Administrative Law, pursuant to Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of the Government Code.

(Added by Stats.1990, c. 1229 (A.B.3588), § 1.)

APPENDIX B: VOCs That May Be Emitted From Building Materials and Cleaning Products

Various VOCs are emitted from building materials and cleaning products. The following table covers only some of the common VOCs and their potential sources in building materials and cleaning products as reported by Levin (1989). (Note that the original list has been modified.) The intent of the list is to cover only some of the more common VOCs emitted from building materials and products. The designation of "potential sources" does not imply that a specific VOC will be found in all the products and materials listed. In addition, the listings of potential sources are not necessarily comprehensive. The VOCs are listed in alphabetical order and synonyms, where applicable, are given in parentheses.

Table B1. VOCs That May Be Emitted From Building Materials and Products and Their Potential Sources	
Chemical Name	Potential Sources
Acetic acid	Solvent for resins, caulks, sealants, glazing compounds, volatile oils
Acetone (2-Propanone)	Lacquer solvent
1-Amyl alcohol (Amyl alcohol; Pentyl alcohol; 1-Pentanol)	Solvent in organic synthesis
Benzaldehyde	Fiberboard, particleboard
Benzene	Adhesives, spot cleaners, alkyd paints, paint removers, particleboard, furniture waxes
2-Butanone (Methyl ethyl ketone)	Floor/wall coverings, fiberboard, caulking compounds, particleboard
n-Butyl acetate (Butyl acetate)	Floor lacquers.
Butyl acrylate (Butyl-2-propenoate)	Used in manufacture of polymers and resins for textile and leather finishes.
n-Butyl alcohol (1-Butanol)	Edge sealings, molding tapes, jointing compounds, cement flagstones, linoleum floor coverings, floor lacquers, industrial cleaners, paint removers
n-Butylbenzene	Solvent
Camphene	Occurs in many essential oils
Chlorobenzene	Solvent for paint, used in manufacture of phenol
Cyclohexane	Solvent for lacquers and resins, paint and varnish removers
Cyclohexanone	Solvent for many resins and waxes
Dibutylphthalate (Di-n-butyl phthalate)	Plasticizer
Diethylamine	Used in resins, dyes, and in manufacture of rubber
Dimethyl acetamide (N,N-Dimethyl acetamide)	Solvent for organic reactions
Dioxane (p-Dioxane; 1,4-Dioxane)	Solvent for many oils, waxes, dyes, cellulose acetate

Table B1 (continued)	
Chemical Name	Potential Sources
Dodecane (n-Dodecane)	Floor varnishes, floor/wall coverings
2-Ethoxyethanol (Cellosolve®; Ethylene glycol monoethyl ether)	Epoxy paints, latex paints, polyurethane varnishes
2-Ethoxyethyl acetate (Cellosolve® acetate; Ethylene glycol monoethyl ether acetate)	Floor lacquers, epoxy paints
Ethyl acetate	Vinyl floor coverings, solvent for varnishes and lacquers
Ethyl alcohol (Ethanol)	Fiberboard, solvents
Ethyl benzene	Floor/wall coverings, insulation foam, chipboard, caulking compounds, jointing compounds, fiberboard, adhesives, floor lacquers, grease cleaners
2-Ethyltoluene (o-Ethyltoluene)	Floor waxes
Formaldehyde (Methanal)	<p><u>Major Sources:</u> MDF, plywood, particleboard, ceiling panels, fiberboard, chipboard</p> <p><u>Minor Sources:</u> Upholstery fabrics, latex-backed fabrics, fiberglass, fiberglass insulation in air ducts, urea formaldehyde foam insulation, wallpaper, caulking compounds, jointing compounds, floor and furniture varnishes, adhesives, floor lacquers, gypsum board</p>
Heptane (n-Heptane)	Floor coverings, floor varnishes
Hexachlorobenzene	Fungicide
Hexanal	Polyurethane wood finish
Hexane (n-Hexane)	Chipboard, gypsum board, insulation board, floor coverings, wallpaper
Isobutyl acetate (2-Methylpropyl acetate)	Floor lacquers
Isobutyl alcohol (Isobutanol; 2-Methyl-1-propanol)	Edge sealings, molding tapes, jointing compounds, cement flagstone, linoleum floor coverings, floor lacquers
Isopropyl alcohol (Isopropanol; 2-Propanol)	Particleboard

Table B1 (continued)	
Chemical Name	Potential Sources
Isoquinolone	Used in synthesis of dyes and insecticides; rubber accelerator
d-Limonene	Paints, adhesives, chipboard, detergents, furniture polish
Methylene chloride (Methane dichloride; Dichloromethane)	Paint removers, aerosol paints, industrial solvents
Methyl isobutyl ketone (MIBK; 4-Methyl-2-pentanone)	Floor/wall coverings
2-Methylpentane (Isohexane)	Chipboard, gypsum board, insulation foam, floor coverings, wallpaper
Nonane (n-Nonane)	Wallpaper, caulking compounds, floor coverings, chipboard, adhesives, cement flagstone, jointing compounds, floor varnishes, floor waxes
Nonyl phenol isomers	Used in manufacture of lubricating oil additives, resins, plasticizers, and surface active agents
Pentachlorophenol (PCP)	Wood preservative, disinfectant, fungicide, paints, wallpaper, adhesives, textiles, wood finishes, floor shampoos
4-Phenylcyclohexene (4-PC; Cyclohexylbenzene)	Manufacturing by-product in carpets with SBR latex backing
α -Pinene	Cement flagstone, fiberboard, gypsum board, adhesives, insulation sheets, chipboard, wood
n-Propyl acetate	Plastics
Propylbenzenes (n-Propyl benzene)	Adhesives, floor/wall coverings, chipboard, paints, caulking compounds, insulation foam
Quinolone	Used in the manufacture of dyes; solvent for resins
Styrene (Vinyl benzene)	Insulation foam, jointing compounds, fiberboard, carpets with SBR latex backing
α -Terpinene (1-Methyl-4-isopropyl-1,3-cyclohexadiene)	Furniture polishes
Tetrachloroethylene (Perchloroethylene)	Widely used in the textile industry for dry cleaning, processing, and finishing of fabrics; used in metal degreasers, spot removers, adhesives, wood cleaners, and lubricants
Table B1 (continued)	

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

Chemical Name	Potential Sources
Tetrachlorophenol	Wood preservative
Toluene	Solvent-based adhesives, water-based adhesives, edge sealings, molding tapes, wallpaper, jointing compounds, floor coverings, vinyl coated wallpaper, caulking compounds, paints, chipboard, vinyl floor coverings
1,1,1-Trichloroethane (Methyl chloroform)	Cleaning fluids, water and stain repellents
Trichloroethylene (TCE)	Solvent for paints and varnishes
1,2,3-Trimethylbenzene	Floor/wall coverings, floor waxes
1,2,4-Trimethylbenzene	Floor/wall coverings, linoleum floor coverings, caulking compounds, vinyl coated wallpaper, jointing compounds, cement flagstone, floor varnishes, chipboard, floor waxes
1,3,5-Trimethylbenzene (Mesitylene)	Caulking compounds, floor/wall coverings, floor waxes
Undecane (n-Undecane)	Wallpaper, gypsum board, floor/wall coverings, joint compounds, chipboard, floor varnishes, paints, paint removers
Xylenes	Adhesives, jointing compounds, wallpaper, caulking compounds, floor coverings, floor lacquers, grease cleaners, varnishes

APPENDIX C: Survey of Product Labeling Programs

A few countries have instituted labeling programs for building materials and products. Following is a discussion of labeling programs from five countries, i.e., United States, Canada, Germany, Denmark, and Sweden.

C1 United States: Carpet and Rug Institute's Carpet Labeling Program

In the United States, the Carpet and Rug Institute (CRI) initiated a voluntary testing program in 1994 as a result of the USEPA's Carpet Policy Dialogue. The testing protocol is based on the ASTM Standard Guide D 5116 - 90 (ASTM, 1990a). The protocol is under consideration at the ASTM and may become a standard guide or method in the future. To qualify for the *CRI Indoor Air Quality Carpet Testing Program Label* the following maximum emission factors for new styrene butadiene rubber (SBR) latex-backed carpet samples collected at the time of manufacture must not be exceeded at 24 hr elapsed time after initiating a test (CRI, 1994a).

1. TVOCs: 500 $\mu\text{g}/\text{m}^2\cdot\text{hr}$.
2. Styrene: 400 $\mu\text{g}/\text{m}^2\cdot\text{hr}$.
3. 4-PC: 100 $\mu\text{g}/\text{m}^2\cdot\text{hr}$.
4. Formaldehyde: 50 $\mu\text{g}/\text{m}^2\cdot\text{hr}$.

C2 United States: Hardwood Plywood and Veneer Association's and National Particleboard Association's Formaldehyde Labeling Program

Tables C1 and C2 list the maximum allowable formaldehyde chamber concentrations under given loading factors as required by: (a) the United States Department of Housing and Urban Development (HUD); (b) the United States Hardwood Plywood and Veneer Association; and (c) the National Particleboard Association.

Table C1. United States Department of Housing and Urban Development (HUD) Guidelines for Formaldehyde ^a (HUD, 1984; HPVA, 1994)		
Product	Concentration (ppm)	Loading Factor (ft ² /ft ³)
Plywood wall panels	0.2	0.29
Particleboard Industrial hardwood plywood panels	0.3	0.13

^a Testing conditions are specified in *Large-Scale Test Method for Determining Formaldehyde Emissions From Wood Products*, *Large Chamber Method FTM 2-1983*, NPA/HPMA for *Manufactured Housing Components* and ASTM Standard E 1333 - 90: *Standard Test Method for Determining Formaldehyde Levels from Pressed Wood Products Under Defined Test Conditions Using a Large Chamber* (ASTM, 1990b).

Ratio of surface area of formaldehyde-containing product to volume of chamber in which the product was tested.

Table C2. National Particleboard Association's Testing and Certification Program for Formaldehyde (Groah and Margosian, 1995)			
Product	Standard	Concentration (ppm)	Loading Factor ^a (ft²/ft³)
Industrial Particleboard	ANSI A208.1-1993	0.3	0.13
Particleboard Flooring	ANSI A208.1-1993	0.2	0.13
Particleboard Decking	HUD	0.3	0.13
MDF	ANSI A208.2-1994	0.3	0.08

^a Ratio of surface area of formaldehyde-containing product to volume of chamber in which the product was tested.

C3 Canada: Canadian Carpet Institute's (CCI) Carpet Labeling Program

CCI has adopted the same carpet testing program as the United States-based CRI. However, research from the Public Works and Government Services of Canada indicated a strong correlation between occupant complaints and 4-PC concentrations. As a result, CCI is considering lowering the maximum allowable emission factor of 4-PC in their labeling program.

C4 Canada: "Ecologo" Program

This program rates residential and architectural coatings based on calculated (i.e., not measured) TVOC contents from product formulations as submitted by product manufacturers. Table C3 (see next page) lists the calculated maximum TVOC emissive content for various material groups that are allowed under this program.

C5 Canada: Ontario Building Environmental Performance Assessment Criteria (BEPAC)

This program was developed as an extension of the Building Research Establishment Environmental Assessment Method (BREEAM) used in the United Kingdom. The following materials and procedures are recommended for the control of VOCs (CMHC, 1994b):

- a) Non-textile floor coverings in common areas;
- b) Fusion-bonded, needle-punched, or other types of low emission carpet backings;
- c) Installation of carpets without adhesives;
- d) Water-based paints, low-odor solvent-based paints, and water-based (low toxicity) adhesives meeting the requirements of Ecologo, Green Cross (name has been changed to: Scientific Certification Systems), or Blue Angel programs (Ecologo and Blue Angel programs are described in Sections C4 and C6 of this appendix); and
- e) Conducting a building bakeout/flashout at >27°C and 1.5 ACH at least one week prior to building occupancy.

Table C3. Specifications of the Canadian "Ecologo" Program (CMHC, 1994a)		
Material	Type	TVOC Emissive Content (g/L)
Paints	water-based	250 ^a
	solvent-based	380
Wood Finishes	water-based	300
	solvent-based	not eligible
Wood Stains	water-based	250
	solvent-based	not eligible
Adhesives	-	20
Caulks and Sealants	-	20

^a 1989 guideline. Likely to be reduced to 200 g/L.

Typical current emissive contents (other than high-gloss enamel paints): 100-150 g/L. Typical emissive contents of high-gloss enamel paints: 250 g/L.

Industry average: 400-450 g/L. Reformulation needed to meet standard.

C6 Germany: "Blue Angel" Environmental Labeling Program

This voluntary labeling program, established in 1977, now consists of approximately 75 product groups including not only building-related products but also consumer products (RAL, 1995). Environmental acceptability of a product is based on a number of factors such as chemical emissions, waste generation, recycling characteristics, associated noise, and use of hazardous substances. An independent Environmental Label Jury determines the criteria and compliance methods and makes final decisions on compliance. The German Institute of Quality and Assurance for Certification administers this program, and the Federal Environmental Agency supervises product testing and application review.

C7 Denmark: Labeling Program

A voluntary program titled "Danish Indoor Climate Labeling System of Building Materials" was initiated in 1994 (Wolkoff, 1994; CMHC, 1994b; Wolkoff and Nielsen, 1995a, 1995b; Nielsen and Wolkoff, 1995; Larsen et al., 1995a, 1995b). This program takes the approach of ranking materials according to the time required for emissions to reach concentrations below the odor and irritation thresholds. The maximum concentrations of selected VOCs are established at half the known odor and irritation thresholds, and the time to reach these concentrations is based on emission measurements or modeling.

C8 Sweden: Flooring Material Labeling Program

This is a voluntary program based on two "trade" standards titled *Measurement of Chemical Emission from Flooring Materials* and *Measurement of Chemical Emission from Smoothing Compounds* (GBR, 1992a, 1992b). Measurements are taken to establish emission factors for TVOCs according to method NT Build 358 (see Section G4 of Appendix G: Survey of Standard Testing Methods) at 4 and 26 week elapsed times. In the case of floor coverings, test samples consist of "newly manufactured, unlaidd surface covering materials," whereas, in the case of smoothing compounds, samples are prepared " 4 ± 1 week after [compound] production" by mixing the dry sample with water. TVOCs represent all organic compounds with boiling points between 50 and 260°C that are adsorbed on Tenax TA® and analyzed using a gas chromatograph equipped with a non-polar column and a flame ionization detector (FID). Formaldehyde and other selected compounds are also included. An "Emission Declaration" form is provided by each manufacturer indicating the product's emissions at 4 and 26 weeks.

The environmental labeling programs of other countries are described in a book titled *Environmental Labeling in OECD Countries* (OECD, 1991).

APPENDIX D: Technical Considerations During Building Bake-Outs

The following is a discussion of problems associated with building bake-outs that are based on the limited experience of CDHS researchers in applying the bake-out procedure in several buildings (as reported by Girman et al., 1987; 1989; and 1990).

1. Achieving bake-out temperatures: HVAC systems are sized for specific thermal and cooling loads which depend on the number of occupants, office equipment, ventilation rate, and outdoor conditions. Thus, attempting to use a building's HVAC system for a bake-out may be problematic. Increased temperatures may be achievable by modifying an HVAC system's temperature controls because most HVAC systems are slightly oversized. Additional heat sources also can be brought into a building (e.g., portable electric heaters), however, kerosene or other unvented combustion heaters should be avoided. A building's lights also can be used as additional heat sources. The final air temperature also will depend on outdoor conditions. If a bake-out is conducted in winter when outdoor temperatures are close to the "design" temperature, it may not be possible to achieve the desired bake-out temperatures. In addition, the fluctuation of a building's air temperature between day and night time must also be taken into consideration. Adjustment of window shades and curtains can maximize solar heat gain during the day and minimize heat loss during the night.
2. Ventilation during bake-out: A certain amount of mechanical ventilation must be provided during a bake-out to minimize adsorption of VOCs by porous materials. The need for increased ventilation must be balanced against the need to achieve and maintain high temperatures. Usually minimum outdoor air quantities are utilized during a bake-out (with maximum recirculation to ensure adequate air mixing throughout the area being baked-out), thereby minimizing the heating load due to ventilation, so that the highest possible indoor temperatures can be achieved. However, Tichenor et al. (1991) caution that a bake-out conducted with minimal ventilation may result in a re-distribution of VOCs from some building materials to others.
3. Duration of bake-out: Ideally a bake-out should be conducted over an extended period of time. However, financial constraints usually limit such a procedure to a few days. It is worth noting that, depending on the thermal mass of a building, it takes at least a day to achieve target air temperatures at the beginning of a bake-out and at least a day to decrease indoor temperatures to comfortable levels after the end of a bake-out. Thus, a total of four days must be allocated to allow two days or less of actual bake-out time.
4. Effectiveness of bake-out on various sources: According to Levin (1992b), a bake-out will not affect all VOC-emitting materials and products in the same manner. Thin materials, with large surface-to-volume ratios (i.e., a large fraction of the mass close to the surface such as paints, varnishes, and waxes), are more likely to be affected by a bake-out than thick materials, with small surface-to-volume ratios (i.e., only a small fraction of the mass close to the surface, such as particleboard).

Another important parameter in determining the effectiveness of a bake-out is the temperature of the various materials during this procedure. Material temperatures depend on a material's thermal mass and on the duration of the bake-out (see Item 3 above), where the thermal mass of a material is determined by multiplying the specific heat of the material by its density. For example, to raise the temperature of a carpet and carpet adhesive sufficiently, the temperature of the sub-floor also must be increased due to the large thermal mass of the carpet assembly. Therefore, materials with large heat capacities are unlikely to be affected by bake-outs of short duration.

5. Cost of bake-outs: There are certain costs involved in a building bake-out besides energy costs. These costs include HVAC modifications, personnel involved with planning and execution of the bake-out, continuous monitoring and adjustment of building temperatures during the bake-out especially in cases when building emergency systems are overridden, etc. In addition, replacement cost of any building materials damaged as a result of the bake-out must be considered. For example Girman et al. (1990) reported that in one of five baked-out buildings there was some material damage consisting of buckled vinyl flooring in one room and a cracked window pane (out of a total of 225 double-glazed windows). The authors also reported that the building with the material damage was the one most extensively baked-out [this building was heated for 102 hr to temperatures up to 100°F (38°C).] The overall cost for this building bake-out was higher than that of the four other buildings, i.e., \$0.23/ft² (\$2.5/m²), but negligible when compared to the cost of the building. Finally, the costs associated with delayed occupancy also must be considered.
6. Other issues: Some of the fire and safety alarms may have to be overridden during a bake-out. In addition, because during a bake-out a building operates well above design temperatures it is important to consider all the related legal and insurance issues. During a bake-out: (a) access to the building should be limited to HVAC maintenance/monitoring personnel; and (b) respirators capable of removing VOCs should be offered to those entering the building.

APPENDIX E: Survey of Existing Guidelines for VOCs (see also Appendix C)

E1 Guidelines for TVOCs

Listed below are guidelines for concentrations and emissions of VOCs as reported by various researchers and organizations. We caution readers that researchers, especially in the United States, strongly debate the applicability of such guidelines. However, we believe that readers should have all available information before making their own decisions. This document does not endorse or oppose any TVOC guidelines.

E1.1 European Guidelines on VOC Concentrations

Although standards for exposure to VOCs in non-industrial settings do not exist, a number of exposure limits have been recommended. The European Collaborative Action (ECA) Report No. 11 titled *Guidelines for Ventilation Requirements in Buildings* (CEC, 1992) lists the following TVOC concentration ranges as measured with a flame ionization detector calibrated to toluene [these recommendations are based on Mølhave's toxicological work on mucous membrane irritation (Mølhave, 1990)].

1. Comfort range: <200 $\mu\text{g}/\text{m}^3$.
2. Multifactorial exposure range: 200 to 3,000 $\mu\text{g}/\text{m}^3$.
3. Discomfort range: 3,000 to 25,000 $\mu\text{g}/\text{m}^3$.
4. Toxic range: >25,000 $\mu\text{g}/\text{m}^3$.

The same European report also lists a second method based on Seifert's work (Seifert, 1990). This method establishes TVOC guidelines based on the ten most prevalent compounds in each of seven chemical classes. The concentrations in each of these classes should be below the maximums listed below.

1. Alkanes: 100 $\mu\text{g}/\text{m}^3$.
2. Aromatic hydrocarbons: 50 $\mu\text{g}/\text{m}^3$.
3. Terpenes: 30 $\mu\text{g}/\text{m}^3$.
4. Halocarbons: 30 $\mu\text{g}/\text{m}^3$.
5. Esters: 20 $\mu\text{g}/\text{m}^3$.
6. Aldehydes and ketones (excluding formaldehyde): 20 $\mu\text{g}/\text{m}^3$.
7. Other: 50 $\mu\text{g}/\text{m}^3$.

The TVOC concentration is calculated by adding the totals from each class. Seifert gives a target TVOC concentration of 300 $\mu\text{g}/\text{m}^3$ which is the sum of the above listed target concentrations. The author also states that no individual compound concentration should exceed 50 percent of the guideline for its class or 10 percent of the TVOC target guideline concentration. However, Seifert states that "...the proposed target value is not based on toxicological considerations but - to the author's best judgement."

E1.2 Tucker's Classification of Low-Emitting Materials and Products

Tucker (1990) reported a classification scheme for determining whether or not materials and products are low-emitting. Tucker assumed that: (a) the maximum indoor concentration of organic vapors from any single source to be 500 $\mu\text{g}/\text{m}^3$; (b) the indoor air to be well mixed; and (c) the ventilation rate to be 0.5 ACH. The author suggested that the maximum emissions in his classification scheme be used only when predictive modeling for IAQ impact is not performed. Tucker's classification scheme is listed in Table E1.

Table E1. Classification of Low-Emitting Materials and Products (Tucker, 1990)	
Material or Product	Maximum Emissions ($\mu\text{g}/\text{m}^2\cdot\text{hr}$)
Flooring materials	600
Flooring coatings	600
Wall materials	400
Wall coatings	400
Movable partitions	400
Office furniture	2,500 ($\mu\text{g}/\text{hr}/\text{workstation}$)

E1.3 State of Washington's Requirements

In 1989, the State of Washington developed indoor air quality specifications for new office buildings as part of the East Campus Plus program (Black et al. 1991a; State of Washington, 1989; *Building with Nature*, 1992). The specifications included, among other requirements, that product emissions from every building material or product should not result in indoor concentrations higher than the ones listed below "within 30 days of installation." (Each product's loading factor was based on a 900 ft³ work station volume.) Test protocols for office furniture and office chairs specified six and four week-long environmental chamber testing periods respectively, in order to "...allow for mathematical modeling of product emission profiles over time" (State of Washington, 1989).

1. TVOCs: 500 $\mu\text{g}/\text{m}^3$.
2. Formaldehyde: 0.05 ppm.
3. 4-PC: 1 ppb.

In addition, the designer/builder was required to disclose in writing any interior design materials, furnishings, or finishes that contained any detectable amounts of compounds listed as carcinogens or reproductive toxins according to: (a) the list of chemical carcinogens as established by the International Agency for Research on Cancer; (b) the list of carcinogens of the National Toxicology Program; and (c) the list of reproductive toxins in the *Catalogue of Teratogenic Agents*.

This protocol also recommended that: (a) the building flush out period to begin 90 days before occupancy; (b) all VOC-emitting material, furniture excluded, to be installed at the beginning of the flush out period; (c) furniture could not be brought in the building earlier than 30 days after the start of the flush out; and (d) the designer/builder was encouraged to continue the flush out before occupancy by the owner.

Mason et al. (1995) reported on the TVOC measurements taken at the Natural Resources Building, which was part of the East Campus Plus building project. TVOC concentrations were reduced 30 to 60% 30 days after the flush out but did not decrease significantly through the 120-day sampling period (flush out ended at 90 days.) However, considerable reductions in TVOC concentrations were noticed at the 266-day sampling period (TVOC concentrations were 15 to 20% of those measured before the flush out.)

Although the East Campus Plus building project is now complete, the State of Washington as well as others continue to refer to the above specifications.

E2 Health Effects and Concentration Guidelines for Selected VOCs

Health effects and concentration guidelines are listed below for selected VOCs. The six VOCs discussed below were selected because: (a) they are common indoor air contaminants; (b) they are listed by the CARB as toxic air contaminants (CARB, 1993b); and (c) they have significant adverse health effects. The selected VOCs are discussed below in alphabetical order: benzene, formaldehyde, methylene chloride, styrene, tetrachloroethylene, and toluene. An identification number known as the **Chemical Abstracts Service (CAS) Registry Number** is also listed for each chemical.

E2.1 Benzene (CAS # 71-43-2)

E2.1.1 Sources

Benzene belongs to the chemical class of aromatic hydrocarbons. It is a constituent of environmental tobacco smoke, automobile exhaust, glues, paints, furniture wax, and detergents. The use of benzene has been discouraged due to its toxicity.

E2.1.2 Exposure Route

The primary route of exposure to benzene is inhalation or ingestion. Skin contact results in defatting and increased absorption of this and other chemicals.

E2.1.3 Health Effects

Information about the health effects of benzene comes from animal and human studies. The range of reported health effects includes death (usually from exposure to high concentrations during exertion with subsequent collapse from heart failure), anesthesia (at concentrations >3000 ppm), intoxication (headache, euphoria, nausea, and giddiness), mild irritation of eyes and mucous membranes, respiratory inflammation, and eye hemorrhage (if systemic poisoning occurs). Major concerns of systemic toxicity of benzene are aplastic anemia and acute myelogenous leukemia, which usually result from chronic exposures but which also may occur after acute exposures (ATSDR, 1993a). Benzene is a known human carcinogen and is listed as such under California Proposition 65 (1994). Benzene also has been identified as a Toxic Air Contaminant by the CARB (1993b) based on its carcinogenicity.

The odor of benzene is characterized as "aromatic/sweet/solvent" (AIHA, 1989). The lowest reported odor detection thresholds are 0.36 ppm (Devos et al., 1990) and 0.78 ppm (AIHA, 1989).

Table E2 lists the short-term exposure thresholds for benzene.

Table E2. Short-Term Exposure Thresholds For Benzene		
Health Effect	Benzene Concentration ^a	Comments and References
Olfactory threshold	See Table E9	
Discomfort / mild effect	0.24 ppm (0.78 mg/m ³)	Transient changes in immune function tests may occur above this concentration (OEHHA, 1995)
Disability or serious effect	1.0 ppm (3.24 mg/m ³)	Developing fetus may be harmed above this concentration (OEHHA, 1995)
Immediately dangerous to life and health (IDLH)	3,000 ppm (9,700 mg/m ³)	NIOSH (1994)

^a Conversion factors for benzene at room air temperature and 1 atm. pressure:
1 ppm = 3.24 mg/m³; 1 mg/m³ = 0.31 ppm.
Interim number.

E2.2 Formaldehyde (CAS # 50-00-0)

E2.2.1 Sources

Formaldehyde belongs to the chemical class of aldehydes, several of which are found in indoor air. Formaldehyde has been of special concern as an indoor air pollutant because of the number of products in which it occurs and the adverse health effects associated with exposure to formaldehyde. Indoor sources of formaldehyde include building materials, particularly pressed wood products (e.g., plywood, MDF, and particleboard), insulation materials (e.g., urea-formaldehyde foam insulation), adhesives, durable-press and flame resistant textiles, combustion appliances, and environmental tobacco smoke. Formaldehyde has been associated with about 4 percent of the building-related illness incidents that NIOSH has investigated (Samet et al., 1988).

E2.2.2 Exposure Route

The primary route of exposure to formaldehyde in the indoor environment is through inhalation. Skin contact with products containing formaldehyde, such as adhesives, results in a localized effect. Uptake into the body and bloodstream from skin exposures is low. Eye exposures similarly have a localized effect.

E2.2.3 Health Effects

Information about the health effects of formaldehyde comes largely from animal studies and from human occupational exposure assessments. The range of health effects observed includes: (a) odor and irritation effects; (b) broader systemic effects; and c) potential carcinogenic effects.

Formaldehyde is a primary upper respiratory tract irritant and its odor is characterized as "pungent" (AIHA, 1989). The lowest listed odor detection threshold is 0.03 ppm (Devos et al., 1990; AIHA, 1989). Devos et al. (1990) reported the mean detection threshold of seven published studies to be 0.87 ppm. Symptoms of eye, nose, and throat irritation, such as tearing, running nose, and a burning sensation in these areas, are relatively common with formaldehyde exposure. People vary widely in their sensitivities to formaldehyde and may respond differently to formaldehyde exposure.

Formaldehyde vapor can irritate the skin directly. Allergic responses (contact dermatitis) also can develop with skin exposure, but the degree of exposure required to cause this is uncertain. Some individuals occupationally exposed to formaldehyde have developed asthma. Chronic lung disease may occur in people exposed to high concentrations of formaldehyde ($>10 \text{ mg/m}^3$).

People with known residential exposures to formaldehyde have reported neuropsychological symptoms, including headache, fatigue, memory and concentration difficulty, and emotional changes. Studies have shown chemical and physical changes in the nervous systems of experimental animals exposed to formaldehyde. Effects of formaldehyde on reproduction, including menstrual disorders, adverse pregnancy outcomes and complications, and low-birth-weight babies have been suggested. However, the human epidemiologic evidence is presently too limited to draw final conclusions.

Formaldehyde is classified as a probable human carcinogen based on sufficient evidence in animal studies. Formaldehyde is very soluble in water and as a result is absorbed readily by the mucous membranes of the upper respiratory tract. Cancer of the nasal cavity has been shown to develop in animals exposed to formaldehyde. Formaldehyde is listed as a California Proposition 65 (1994) carcinogen and as a Toxic Air Contaminant by the CARB (1993b) based potential carcinogenicity.

Table E3 lists some effects of short-term formaldehyde exposure in humans.

Table E3. Short-Term Exposure Thresholds For Formaldehyde		
Health Effect	Formaldehyde Concentration ^a	Comments and References
Olfactory threshold	See Table E9	
Discomfort / mild effect	0.14 ppm (0.17 mg/m^3)	Eye irritation (OEHHA, 1995)
Disability or serious effect	10 ppm (12 mg/m^3)	Tearing eyes (OEHHA, 1995)
Immediately dangerous to life and health (IDLH)	20 ppm (24 mg/m^3)	NIOSH (1994)

^a Conversion factors for formaldehyde at room air temperature and 1 atm. pressure:
 1 ppm = 1.24 mg/m^3 ;
 1 mg/m^3 = 0.815 ppm.
 Interim number.

E2.2.4 Guidelines for Formaldehyde

The following organizations have issued guidelines for formaldehyde.

1. The California Department of Health Services recommends 0.05 ppm as an "indoor air concentration guideline" for homes (CARB, 1991).
2. The California Air Resources Board recommends for homes an "action level" of 0.10 ppm (0.12 mg/m^3) and a "target level" of 0.05 ppm (0.06 mg/m^3) or lower (CARB, 1991).
3. The United States Department of Housing and Urban Development (HUD, 1984) recommends for manufactured homes that chamber formaldehyde concentrations for plywood wall panels should not exceed 0.2 ppm and for particleboard 0.3 ppm. In addition, HUD recommends that indoor

formaldehyde concentrations of manufactured homes from all sources including plywood and particleboard should not exceed 0.4 ppm.

4. The World Health Organization (WHO) guideline is 0.082 ppm (WHO, 1987b).
5. The California Environmental Protection Agency, the Office of Environmental Health Hazard Assessment (OEHHA) in a draft document lists an acute 1-hr exposure concentration of 0.14 ppm (0.17 mg/m³), based on early symptoms of eye irritation. This draft is presently undergoing public review (OEHHA, 1995).

E2.3 Methylene Chloride (CAS # 75-9-2)

E2.3.1 Sources

Methylene chloride or dichloromethane is a chlorinated solvent. It is commonly used as an industrial solvent and paint remover, in aerosol products, and in some spray paints. Indoor air concentrations during the use of paint removers containing methylene chloride in non-occupational settings have averaged 460 to 2980 mg/m³ in an unventilated room (WHO, 1987b). Methylene chloride is a common indoor air contaminant. It is also measurable in ambient air as a result of industrial and end product uses, with background concentrations usually less than 1 ppb (3.5 g/m³).

E2.3.2 Exposure Route

Methylene chloride is absorbed well by inhalation and the oral route if ingested. Skin absorption is generally minor.

E2.3.3 Health Effects

Absorbed methylene chloride may be broken down into other chemicals in the body, including carbon monoxide, or may be released unchanged. The health effects of methylene chloride have been determined largely from animal studies although some studies of occupational exposures have been done. Relatively little is known about potential health effects of long-term, low-level exposures to methylene chloride, such as those that occur in non-occupational or environmental settings.

The odor of methylene chloride is characterized as "sweet" (AIHA, 1989). The lowest reported odor detection thresholds are 1.2 ppm (AIHA, 1989) and 10 ppm (Devos et al., 1990). Carbon monoxide is formed during the breakdown of methylene chloride in the body. Carbon monoxide binds to hemoglobin in the blood, forming carboxyhemoglobin, and destroys the ability of the bound hemoglobin to carry oxygen to the tissues. This carboxyhemoglobin may form in addition to that formed from other carbon monoxide sources, such as cigarette smoke and automotive exhaust, causing an added stress to the body. The WHO suggests that a 24-hr exposure to methylene chloride not exceed 3 mg/m³ to limit the corresponding carboxyhemoglobin formation to less than 0.1 percent in the body (WHO, 1987b).

Methylene chloride affects the nervous system. Brief human exposures of 1 to 2 hr or less to 300 ppm methylene chloride can temporarily affect vision and hearing. Higher exposures may affect reaction time and steadiness, and long-term exposures to very high concentrations (500 to 1000 ppm) can cause permanent neurologic damage. The Agency for Toxic Substances and Disease Registry (ATSDR) has recommended a short-term inhalation Minimum Risk Level (MRL) of 0.4 ppm, based on human evidence for nervous system toxicity (ATSDR, 1993b). Short-term exposures to methylene chloride at or below this concentration are not believed to be a concern with respect to non-cancer health effects in the general

population. The OEHHA in a draft document (OEHHA, 1995) lists an acute, 1-hr exposure concentration of 24 ppm (83 mg/m³) based on subtle impairment of the central nervous system.

Exposures to methylene chloride have been shown to cause liver and kidney damage in animal studies. The lowest exposure level at which liver and kidney toxicity have been seen in animal studies is 25 ppm for approximately 3 mo. Human studies are limited regarding potential effects of methylene chloride on the liver or kidney. The ATSDR has developed an inhalation MRL for intermediate exposures (2 wk to 1 yr) of 0.03 ppm based on animal studies. No longer-term inhalation MRL has been developed.

Methylene chloride has been shown to cause cancer in animal studies and it is classified as a probable human carcinogen based on sufficient animal evidence. Methylene chloride also is listed as a California Proposition 65 (1994) carcinogen and as a Toxic Air Contaminant by the CARB (1993b) based on its cancer-causing potential. Increases in lung and liver cancer, benign mammary tumors, salivary gland cancer, and leukemia have been seen in animal studies. Long-term follow up of chemical factory workers exposed to methylene chloride suggests a possible association with liver and biliary tract cancers (USEPA, 1995). The latter human evidence is not conclusive at this time.

Table E4 lists a summary of health effects from short-term exposure to methylene chloride.

Table E4. Short-Term Exposure Thresholds For Methylene Chloride		
Health Effect	Methylene Chloride Concentration ^a	Comments and References
Olfactory threshold	See Table E9	
Discomfort / mild effect	24 ppm (83 mg/m ³)	Subtle central nervous system impairment (OEHHA, 1995)
Disability or serious effect	No threshold established	OEHHA (1995)
Immediately dangerous to life and health (IDLH)	2300 ppm (7980 mg/m ³)	NIOSH (1994)

^a Conversion factors for methylene chloride at room air temperature and 1 atm. pressure:
 1 ppm = 3.47 mg/m³;
 1 mg/m³ = 0.28 ppm.
 Interim number.

E2.4 Styrene (CAS # 100-42-5)

E2.4.1 Sources

Styrene belongs to the chemical class of aromatic hydrocarbons. It is a constituent of automobile exhaust, environmental tobacco smoke, building materials, and consumer products (e.g., polystyrene used in packaging, toys, housewares, and appliances may contain small amounts of unlinked styrene).

E2.4.2 Exposure Route

The primary route of exposure to styrene is by inhalation. It can be absorbed readily by the skin into the body.

E2.4.3 Health Effects

Information about the health effects of styrene come from animal and human studies. The range of reported health effects include respiratory inflammation or asthma, intoxication (depression, difficulty concentrating, headache, euphoria, nausea, and giddiness), irritation of eyes and mucous membranes, and neurological damage (ATSDR, 1992a). The neurological damage associated with styrene exposure includes slowing in sensory nerves and central nervous system depression (Cherry and Gautrin, 1990). There is no direct evidence for human reproductive or developmental toxicity from styrene exposure. Styrene has been identified as a Toxic Air Contaminant by the CARB (1993b).

The odor of styrene is characterized as "sharp/sweet" (AIHA, 1989). The lowest reported odor detection thresholds are 4.7 ppb (AIHA, 1989) and 52 ppb (Devos et al., 1990).

Table E5 lists a summary of health effects from short-term exposure to styrene.

Table E5. Short-Term Exposure Thresholds For Styrene		
Health Effect	Styrene Concentration ^a	Comments and References
Olfactory threshold	See Table E9	
Discomfort / mild effect	5.1 ppm (21.4 mg/m ³)	OEHHA (1995)
Disability or serious effect	No threshold established	OEHHA (1995)
Immediately dangerous to life and health (IDLH)	No threshold established	

^a Conversion factors for styrene at room air temperature and 1 atm. pressure:
 1 ppm = 4.2 mg/m³;
 1 mg/m³ = 0.24 ppm.
 Interim number.

E2.4.4 Guidelines for Styrene

An acute toxicity exposure concentration of 5.1 ppm has been recommended for styrene, based on lack of human eye and throat irritation symptoms below 51 ppm and allowing for a 10-fold margin of safety for individual variation (OEHHA, 1995).

E2.5 Tetrachloroethylene (perchloroethylene or ethylene tetrachloride) (CAS # 127-18-4)

E2.5.1 Sources

Tetrachloroethylene is a VOC which is also known as perchloroethylene (PCE) and ethylene tetrachloride. It is commonly used as a dry-cleaning solvent and as a metal degreaser. Tetrachloroethylene is used in building materials and various consumer products including spot removers, lubricants, adhesives, and wood cleaners (ATSDR, 1992b). Tetrachloroethylene has been measured in the indoor air of homes, new and occupied office buildings, and ambient air. Indoor air concentrations have been measured up to 250 g/m³ (35 ppb) (WHO, 1987b).

E2.5.2 Exposure Route

Tetrachloroethylene is absorbed well by the inhalation route and the oral route if ingested. Absorption through the skin is relatively low.

E2.5.3 Health Effects

Much of what is known about the health effects of tetrachloroethylene comes from animal studies and some occupational studies. Most of these studies involve relatively high exposures to tetrachloroethylene. Less is known about the health effects of low-level, long-term exposures to tetrachloroethylene.

The odor of tetrachloroethylene is characterized as "etherish" (AIHA, 1989). The lowest reported odor detection threshold is 2 ppm (AIHA, 1989) and 3 ppm (Devos et al., 1990). Once absorbed into the body, the liver is a main target organ for the toxic effects of tetrachloroethylene. The central nervous system and the kidney also can be affected. Short-term exposures to tetrachloroethylene concentrations of 200 ppm or higher cause liver toxicity in animal studies. Symptoms of eye and respiratory irritation have been observed in humans briefly exposed (< 2 hr) to between 100 and 200 ppm tetrachloroethylene. Central nervous system effects of tetrachloroethylene, depending on concentration, include changes in mood, behavior, or coordination and anesthetic effects. The ATSDR has established a short-term inhalation MRL for tetrachloroethylene of 0.6 ppm for the general population, based on central nervous system depression in adults exposed to 100 ppm for the equivalent of a work week. Short-term exposures to concentrations at or below this number are not believed to cause adverse non-cancer health effects for the general population. The OEHHA, in a draft document (OEHHA, 1995), lists an acute, 1-hr exposure concentration of 1.7 ppm (12 mg/m³), based on loss of normal coordination and irritant effects.

Longer exposures to tetrachloroethylene at lower concentrations can also have adverse effects. Liver toxicity was seen in mice exposed by inhalation to 9 ppm tetrachloroethylene for a month. The ATSDR established an intermediate-duration (2 wk to 1 yr), inhalation MRL of 0.009 ppm for the general population based on this study. Occupational exposures at 12 ppm for 4 to 5 mo have been associated with impaired perception, attention, and intellectual skills. Mild kidney damage has been associated with long-term occupational exposures to 10 ppm tetrachloroethylene. Although not conclusive, some epidemiological studies suggest an association between occupational exposures to tetrachloroethylene and adverse reproductive effects, primarily menstrual disorders and spontaneous abortions.

Tetrachloroethylene is listed as a carcinogen under California's Proposition 65 (1994) and as a Toxic Air Contaminant by the CARB (1993b) based on its carcinogenicity. Tetrachloroethylene has been shown to cause liver cancer and leukemia in animal studies, by both oral and inhalation exposures, and is considered to be a potential human carcinogen based on animal data. Some human epidemiological studies of dry cleaning workers also suggest an association between exposure to solvents, including tetrachloroethylene, and increased cancer risk. Table E6 lists a summary of health effects from short-term exposure to tetrachloroethylene.

Table E6. Short-Term Exposure Thresholds For Tetrachloroethylene		
Health Effect	Tetrachloroethylene Concentration ^a	Comments and References
Olfactory threshold	See Table E9	
Discomfort / mild effect	No threshold established	
Disability or serious effect	1.7 ppm (12 mg/m ³)	Loss of coordination, headache, eye, nose, and throat irritation, and light headiness (OEHHA, 1995)
Immediately dangerous to life and health (IDLH)	150 ppm (1017 mg/m ³)	NIOSH (1994)

^a Conversion factors for tetrachloroethylene at room air temperature and 1 atm. pressure:

1 ppm = 6.78 mg/m³;

1 mg/m³ = 0.15 ppm.

Interim number.

E2.6 Toluene (CAS # 108-88-3)

E2.6.1 Sources

Toluene belongs to the chemical class of aromatic hydrocarbons. Toluene is present in gasoline, automobile exhaust, environmental tobacco smoke, paints, fingernail polishes, glues, and building materials.

E2.6.2 Exposure Route

The primary route of exposure to toluene is by inhalation. It can also cross the skin into the body. Toluene, like other organic hydrocarbon solvents, can dissolve the skin's natural protective oils, and prolonged or frequent contact may cause irritation or cracking of the skin.

E2.6.3 Health Effects

Information about the health effects of toluene come from animal and human studies. The range of health effects reported include intoxication (i.e., headache, nausea, difficulty concentrating, euphoria, and giddiness followed by depression), respiratory inflammation, worsening of asthma, irritation of eyes and mucous membranes, and neurological damage. Toluene may cause changes in the heart leading to abnormal heart rhythms or death. The neurological damage associated with toluene exposure may include alteration in a person's balance, speech, hearing, muscle control, memory, and thinking abilities. Kidney

function may be affected, but generally returns to normal after cessation of exposure. Animals exposed to toluene have demonstrated effects on the liver, kidneys, and lungs.

The odor of toluene is characterized as "sour/burnt" (AIHA, 1989). The lowest reported odor detection thresholds are 0.021 ppm (AIHA, 1989) and 0.11 ppm (Devos et al., 1990). Exposure of unborn animals to toluene resulted in harm when high concentrations were breathed by the mothers. Women who abused toluene throughout their pregnancy (e.g., by "sniffing" glue or paint) have delivered children with birth defects and delayed development. However, it is not known if toluene can affect pregnancy or other reproductive function at concentrations normally found in indoor air.

Schmid et al. (1985) and Bauchinger et al. (1982) reported chromosomal damage in workers with prolonged exposures to toluene concentrations between 200 and 300 ppm. Chromosomes contain information that tells a person's body cells how to function and form new cells. The long-term effects of chromosome damage are not known, but may include increased risk of cancer. No other evidence has been published to suggest that toluene by itself causes cancer. Studies that suggest that toluene is a carcinogen may be due to the use of commercial products contaminated with small amounts of benzene, a known carcinogen. Toluene has been identified as a Toxic Air Contaminant by the CARB (1993b).

Table E7 summarizes the nervous system effects of toluene and the acute toxicity exposure levels for 1-hr exposure to toluene.

Table E7. Short-Term Exposure Thresholds For Toluene		
Health Effect	Toluene Concentration ^a	Comments and References
Olfactory threshold		See Table E9
Discomfort / mild effect	9.8 ppm (37 mg/m ³)	OEHHA (1995)
Disability or serious effect	12.3 ppm (46 mg/m ³)	Exposure above this concentration may harm a developing fetus (OEHHA, 1995)
Immediately dangerous to life and health (IDLH)	2000 ppm (7500 mg/m ³)	NIOSH (1994)

^a Conversion factors for toluene at room air temperature and 1 atm. pressure:
 1 ppm = 3.75 mg/m³; 1 mg/m³ = 0.27 ppm.
 Interim number.

E2.6.4 Guidelines for Toluene

An acute toxicity exposure concentration of 9.8 ppm (37 mg/m³) has been recommended for toluene (OEHHA, 1995). This recommendation is based on studies showing perceived impaired reaction time, headache, dizziness, intoxication symptoms, and slight eye and nose irritation in 16 healthy males exposed to 100 ppm of toluene over a 6-hr period, with no reported symptoms at a concentration of 40 ppm over a 6-hr period. The results of these studies were extrapolated to a 1-hr exposure period allowing for a ten-fold margin of safety for individual variation (OEHHA, 1995).

E3 Sources of Information on Carcinogenicity and Reproductive Toxicity of VOCs

There are several sources listing information on the carcinogenicity and reproductive toxicity of VOCs.

Some of these sources are listed below.

1. In California, the OEHHA has been designated by the Governor to publish at least annually a list of chemicals "...known to the State to cause cancer or reproductive toxicity" (California Proposition 65, 1994). Publication of this list is required by the Safe Drinking Water and Toxic Enforcement Act of 1986.
2. Also in California, the CARB has developed a list of Toxic Air Contaminants as mandated under Chapter 3.5 of the California Health and Safety Code. A number of these contaminants have been determined by the CARB's Scientific Review Panel to be carcinogenic (CARB, 1993b). For those contaminants designated as carcinogenic, the CARB has developed various control measures to reduce emissions outdoors.
3. The Working Group on the Evaluation of Carcinogenic Risks to Humans of the International Agency for Research on Cancer (IARC) publishes, in the form of monographs, critical reviews of data on the carcinogenicity of agents to which humans are likely to be exposed. The Working Group evaluates these data and decides whether on not sufficient data exist on carcinogenicity for humans and animals. The Working Group then lists each agent's carcinogenic potential to humans. The Working Group lists the carcinogenic potential of each agent in Group 1, 2A, 2B, or 3. **Group 1** agents are considered human carcinogens based on sufficient evidence in humans; **Group 2A** agents are listed as probable human carcinogens based on limited evidence in humans and sufficient evidence in animals; **Group 2B** agents are listed as possible human carcinogens based on inadequate evidence in humans but sufficient evidence in animals, or limited evidence in humans without sufficient evidence in animals; and **Group 3** agents are not classifiable as human carcinogens.

Some of the chemicals listed under Proposition 65 and by the IARC are VOCs emitted from building materials and are likely to be found in office environments. Table E8 (see next page) lists some of these chemicals. The reader is cautioned that the intent of the following table is to cover the most common carcinogenic VOCs emitted by building materials and products and not to list all possible indoor carcinogens emitted by building materials and products or other sources. Note that all the chemicals shown on Table E8 are listed also as Toxic Air Contaminants by the CARB (CARB, 1993b).

E4 Sensory Effects of VOCs

Humans are able to detect both odor and irritant effects of many VOCs. However, these two effects cannot be easily differentiated by most humans. A number of indicators or substitute measures may be used to estimate or predict the odor and irritation potency of VOCs as discussed below. The reader is cautioned that the mere presence of a chemical with odor or irritation potential does not imply adverse health effects. Other factors that must be considered are concentration, proximity of occupants to VOC-emitting sources, and duration of exposure as discussed in Section 2.2.1.

Table E8. VOCs Emitted By Building Materials Known or Suspected To Be Human Carcinogens or Reproductive Toxicants				
Chemical Name	Listed as Carcinogen			Listed as Reproductive Toxicant
	California Prop. 65 ^a	CARB	IARC Group	California Prop. 65
Benzene	Yes	Yes	1	No
Carbon tetrachloride (Tetrachloromethane)	Yes	Yes	2B	No
Dioxane (p-Dioxane; 1,4-Dioxane)	Yes	No	2B	No
Formaldehyde (Methanal)	Yes	Yes	2A	No
Methylene chloride (Methane chloride; Dichloromethane)	Yes	Yes	2B	No
Styrene (Vinyl benzene)	(oxide) Yes	No	2B	No
Tetrachloroethylene (Perchloroethylene; 1,1,2,2-Tetrachloroethylene)	Yes	Yes	2B	No
Toluene	No	No	3	Yes
Trichloroethylene (TCE)	Yes	Yes	3	No

- ^a Chemical known to the State of California to cause cancer (California Proposition 65, 1994);
Chemical listed in the CARB's Toxic Air Contaminant List and determined by the Scientific Review Panel to be carcinogenic (CARB, 1993b);
Chemical listed by the IARC as: Group 1 ("human carcinogen"); Group 2A ("probable human carcinogen"); Group 2B ("possible human carcinogen"); and Group 3 ("not classifiable human carcinogen") (IARC, 1987, 1989);
Chemical known to the State of California to cause reproductive toxicity (California Proposition 65, 1994);
See Section E2.1 of Appendix E for a detailed discussion of this chemical;
Chemical listed in the CARB's Toxic Air Contaminant List (CARB, 1993b);
See Section E2.2 of Appendix E for a detailed discussion of this chemical;
See Section E2.3 of Appendix E for a detailed discussion of this chemical;
See Section E2.4 of Appendix E for a detailed discussion of this chemical;
See Section E2.5 of Appendix E for a detailed discussion of this chemical;
See Section E2.6 of Appendix E for a detailed discussion of this chemical.

E4.1 Odor

The most common index for measuring the presence of an odorous chemical is the odor threshold. There are two types of odor thresholds: the **detection** and **recognition** thresholds. These thresholds are the lowest concentrations of an odorous chemical at which a specified percentage, usually 50 percent, of a panel of at least six judges "detects a stimulus as being different from odor-free blanks" (i.e., detection threshold) or ascribes "a definite character to the odor" (i.e., recognition threshold) (AIHA, 1989).

Reported odor threshold data vary considerably, sometimes as much as four orders of magnitude for the same chemical. Reasons for this variability include differences in experimental methodologies and in human olfactory responses. The two most widely used odor threshold references are AIHA (1989) and Devos et al. (1990).

AIHA (1989) lists detection and recognition threshold values for 182 chemicals that have established threshold limit values (TLVs). AIHA critiqued multiple studies, and only data from those studies that met AIHA's threshold determination criteria were used to calculate geometric mean detection and recognition thresholds for the 182 chemicals. AIHA (1989) also lists odor thresholds from all individual studies, highlighting those used for the calculation of the geometric mean values.

Similarly, Devos et al. (1990) compiled a list of standardized human olfactory (i.e., odor) thresholds for 529 chemicals. Each standardized threshold is presented as a weighted average of data from published studies for each chemical. Odor thresholds from individual studies are also included for comparison to the weighted average.

Table E9 lists detection odor thresholds from the above references for the VOCs listed in Appendix B. Differences exceeding one order of magnitude exist between the two references for some VOCs. This discrepancy illustrates the variability of existing odor threshold data. The lowest odor threshold listed in Table E9 is for 1,3,5-trimethylbenzene (i.e., 2.2 ppb). Other VOCs with low odor thresholds include 1,2,4-trimethylbenzene (i.e., 2.4 ppb), butyl acrylate (i.e., 2.6 ppb), and ethyl benzene (i.e., 2.9 ppb). Note that many of the listed compounds have odor thresholds significantly higher than typical indoor concentrations.

E4.2 Irritation

Most skin and eye irritation information is obtained from tests using rabbits. The **Draize** procedure specifies the experimental methodologies for the skin and eye irritation tests. Both of these tests are relatively simple to conduct. The Draize procedure can adequately identify most of the moderate to severe human eye or skin irritants, but the procedure often fails to detect mild or subtle irritation. The Draize assessment of severity of different eye or skin effects is based on a subjective grading system which, as in the case of odor thresholds, is one of the main sources of discrepancy among data reported by various researchers. Skin and eye irritation information for humans is available for some chemicals.

Two of the most widely used sources for irritation information are NIOSH (1994) and Sax and Lewis (1989). The irritation data listed in both references are based on Draize tests in rabbits and on human exposure data where available. Table E9 lists irritation characteristics for the VOCs presented in Appendix B. All VOCs listed in Table E9 have irritation information available, and 85 percent of these compounds exhibit some type of irritation. Among the VOCs that are listed as irritants, over 90 percent cause eye irritation, over 95 percent cause skin irritation, and over 85 percent cause both types of irritation.

Table E9. Odor Thresholds and Irritation Characteristics for VOCs Known or Suspected of Being Emitted From Building Materials and Cleaning Products						
Chemical Name	CAS #	Odor Threshold		Irritant Characteristics		
		AIHA ^a	Devos et al.	Irritant (+/)	Type of Irritation	Ref.
Acetic acid	64-19-7	0.074 ppm	0.14 ppm	+	Eye, skin, nose	1
					Severe eye and skin	2
Acetone (2-Propanone)	67-64-1	62 ppm	14 ppm	+	Eye, nose, throat	1
					Skin, severe eye	2
1-Amyl alcohol (Amyl alcohol; Pentyl alcohol; 1-Pentanol)	71-41-0	Not listed	0.47 ppm	+	Eye, upper resp., severe skin and eye	2
Benzaldehyde	100-52-7	Not listed	0.04 ppm	+	Skin	2
Benzene	71-43-2	61 ppm	3.6 ppm	+	Eye, skin, nose	1
					Severe eye, skin	2
2-Butanone (Methyl ethyl ketone)	78-93-3	16 ppm	7.8 ppm	+	Eye, skin, nose	1
						2
n-Butyl acetate (Butyl acetate)	123-86-4	0.31 ppm	0.19 ppm	+	Eye, skin, upper resp. system	1
					Skin, severe eye	2
Butyl acrylate (Butyl-2-propenoate)	141-32-2	None accepted	2.6 ppb	+	Eye, skin, upper resp. system	1
					Skin and eye	2

Table E9 (continued)						
Chemical Name	CAS #	Odor Threshold		Irritant Characteristics		
		AIHA ^a	Devos et al.	Irritant (+/)	Type of Irritation	Ref.
n-Butyl alcohol (1-Butanol)	71-36-3	1.2 ppm	Not listed	+	Eye, nose, throat	1
					Skin, severe eye	2
n-Butylbenzene	104-51-8	Not listed				2
Camphene	79-92-5	Not listed				2
Chlorobenzene	108-90-7	1.3 ppm	0.74 ppm	+	Eye, skin, nose	1
					"Slight irritant"	2
Cyclohexane	110-83-8	780 ppm	22 ppm	+	Eye, skin, resp. system	1
					Skin	2
Cyclohexanone	108-94-1	3.5 ppm	0.71 ppm	+	Eye, skin, mucous membrane	1
					Skin, severe eye irritant	2
Dibutylphthalate (Di-n-butyl phthalate)	84-74-2	Not listed		+	Eye, upper resp. system	1
						2
Diethylamine	109-89-7	0.053 ppm	0.19 ppm	+	Eye, skin, resp. system	1
					Skin, severe eye irritant	2
Dimethyl acetamide (N,N-Dimethyl acetamide)	127-19-5	Not listed	48 ppm	+	Skin	1, 2

Table E9 (continued)						
Chemical Name	CAS #	Odor Threshold		Irritant Characteristics		
		AIHA*	Devos et al.	Irritant (+/)	Type of Irritation	Ref.
Dioxane (p-Dioxane; 1,4-Dioxane)	123-91-1	12 ppm	5.5 ppm	+	Eye, skin, nose, throat	1
					Eye, skin	2
Dodecane (n-Dodecane)	112-40-3	Not listed	2.0 ppm			2
				+	Mucous membrane by analogy	4
2-Ethoxyethanol (Cellosolve®, Ethylene glycol monoethyl ether)	110-80-5	2.7 ppm	1.2 ppm	+	Eye, resp. system	1
					Eye, skin	2
2-Ethoxyethyl acetate (Cellosolve® acetate, Ethylene glycol monoethyl ether acetate)	111-15-9	0.060 ppm	0.18 ppm	+	Eye, nose	1
					Skin, eye	2
Ethyl acetate	141-78-6	18 ppm	2.6 ppm	+	Eye, skin, nose, throat	1
					Eye	2
Ethyl alcohol (Ethanol)	64-17-5	180 ppm	29 ppm	+	Eye, skin, nose	1
					Eye, severe skin	2
						4
Ethyl benzene	100-41-4	See footnote	2.9 ppb	+	Eye, skin, mucous membrane	1
					Eye, skin	2

Table E9 (continued)						
Chemical Name	CAS #	Odor Threshold		Irritant Characteristics		
		AIHA ^a	Devos et al.	Irritant (+/)	Type of Irritation	Ref.
2-Ethyltoluene (o-Ethyltoluene)	611-14-3	Not listed				2
				+	Mucous membrane by analogy	4
Formaldehyde (Methanal)	50-00-0	See footnote	0.87 ppm	+	Eye, nose, throat, resp. system	1
					Eye, skin	2
Heptane (n-Heptane)	142-82-5	230 ppm	9.8 ppm			1, 2
Hexachlorobenzene	118-74-1	Not listed				2
Hexanal	66-25-1	Not listed	14 ppb	+	Eye, skin	2
Hexane (n-Hexane)	110-54-3	See footnote	22 ppm	+	Eye, nose	1
					Eye, resp. tract	2
Isobutyl acetate (2-Methylpropyl acetate)	110-19-0	1.1 ppm	Not listed	+	Eye, skin, upper resp. system	1
					Skin, eye	2
Isobutyl alcohol (Isobutanol; 2-Methyl-1-propanol)	78-83-1	3.6 ppm	0.83 ppm	+	Eye, throat	1
					Severe skin and eye	2
Isopropyl alcohol (Isopropanol; 2-Propanol)	67-63-0	43 ppm	10 ppm	+	Eye, nose, throat	1
					Eye, skin	2
Isoquinolone	119-65-3	Not listed		+	Severe skin and eye	2

Table E9 (continued)						
Chemical Name	CAS #	Odor Threshold		Irritant Characteristics		
		AIHA ^a	Devos et al.	Irritant (+/)	Type of Irritation	Ref.
d-Limonene	5989-27-5	Not listed	0.44 ppm			2
Methylene chloride (Methane dichloride; Dichloromethane)	75-09-02	See footnote	28 ppm	+	Eye, skin	1
					Eye, severe skin	2
Methyl isobutyl ketone (MIBK; 4-Methyl-2-pentanone)	108-10-1	0.88 ppm	Not listed	+	Eye, skin, mucous membrane	1
				+	Very irritating to eye, skin, and mucous membrane	2
2-Methylpentane (Isohexane)	107-83-5	Not listed		+	Eye	2
Nonane (n-Nonane)	111-84-2	See footnote	1.3 ppm	+	Eye, skin, nose, throat	1
					Resp. tract	2
Nonyl phenol isomers	25154-52-3	Not listed		+	Severe skin and eye	2
Pentachlorophenol (PCP)	87-86-5	Not listed		+	Eye, nose, throat	1
					Skin	2
4-Phenylcyclohexene (4-PC; Cyclohexylbenzene)	827-52-1	Not listed				2
α -Pinene	80-56-8	Not listed	0.69 ppm	+	Eye, mucous membrane, severe skin	2

Table E9 (continued)						
Chemical Name	CAS #	Odor Threshold		Irritant Characteristics		
		AIHA ^a	Devos et al.	Irritant (+/)	Type of Irritation	Ref
n-Propyl acetate	109-60-4	0.18 ppm	0.58 ppm	+	Eye, nose, throat	1
					Skin	2
Propylbenzenes (n-Propylbenzene)	103-65-1	Not listed				2
Quinoline	91-22-5	Not listed	15 ppb	+	Skin, severe eye	2
Styrene (Vinyl benzene)	100-42-5	0.14 ppm	0.14 ppm	+	Eye, nose, resp. system	1
					Skin, eye	2
α-Terpinene (1-Methyl-4-isopropyl-1,3-cyclohexadiene)	99-86-5	Not listed				2
Tetrachloroethylene (Perchloroethylene)	127-18-4	47 ppm	6.2 ppm	+	Eye, nose, throat	1
					Eye, severe skin	2
Tetrachlorophenol	25167-83-3	Not listed				2
Toluene	108-88-3	1.6 ppm	1.6 ppm	+	Eye, nose	1
					Skin, eye	2
1,1,1-Trichloroethane (Methyl chloroform)	71-55-6	390 ppm	22 ppm	+	Eye, skin	1
					Skin, severe eye	2
Trichloroethylene (TCE)	79-01-6	82 ppm	4.9 ppm	+	Eye, skin	1
					Eye, severe skin	2

Table E9 (continued)						
Chemical Name	CAS #	Odor Threshold		Irritant Characteristics		
		AIHA ^a	Devos et al.	Irritant (+/)	Type of Irritation	Ref
1,2,3-Trimethylbenzene	526-73-8	Not listed		+	Eye, skin, nose, throat, resp. system	1
						2
1,2,4-Trimethylbenzene	95-63-6	2.4 ppb	0.15 ppm	+	Eye, skin, nose, throat, resp. system	1
						2
1,3,5-Trimethylbenzene (Mesitylene)	108-67-8	2.2 ppb	0.23 ppm	+	Eye, skin, nose, throat, resp. system	1
						2
Undecane (n-Undecane)	1120-21-4	Not listed	1.2 ppm			2
				+	Mucous membrane by analogy	4
m-Xylene (1,3-Dimethylbenzene)	108-38-3	0.62 ppm	0.32 ppm	+	Eye, skin, nose, throat	1
					Severe skin	2
o-Xylene (1,2-Dimethylbenzene)	95-47-6	5.4 ppm	0.85 ppm	+	Eye, skin, nose, throat	1
						2
p-Xylene (1,4-Dimethylbenzene)	106-42-3	2.1 ppm	0.49 ppm	+	Eye, skin, nose, throat	1
						2

^a Reference: AIHA. 1989. *Odor Thresholds for Chemicals with Established Occupational Health Standards*. Akron, Ohio: American Industrial Hygiene Association; Concentrations listed are detection thresholds;
Reference: Devos, M.; Patte, F.; Rouault, J.; Laffort P.; and Van Gemert, L.J., Editors. 1990. *Standardized Human Olfactory Thresholds*. New York, New York: Oxford University Press;
+: mention of irritant effect in references; : no mention of irritant effects in references;
By analogy to chemically similar compounds;
See Section E2.1 of Appendix E for a detailed discussion of this chemical;

See Section E2.2 of Appendix E for a detailed discussion of this chemical;
See Section E2.3 of Appendix E for a detailed discussion of this chemical;
See Section E2.4 of Appendix E for a detailed discussion of this chemical;
See Section E2.5 of Appendix E for a detailed discussion of this chemical;
See Section E2.6 of Appendix E for a detailed discussion of this chemical;
None of the literature critiqued by AIHA met the odor threshold determination criteria.

References used to obtain irritant characteristics for Table E9 (numbers correspond to the last column of Table E9)

1. NIOSH. 1994. *NIOSH Pocket Guide to Chemical Hazards*, United States Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-116. Available from the U.S. Government Printing Office, Superintendent of Documents, Washington, DC (stock no. 017-033-00473-1) and the National Technical Information Service, Springfield, VA (stock no. PB95-100368).
2. Sax, N. I; and Lewis, J., Sr. 1989. *Dangerous Properties of Industrial Materials*. New York, New York: Van Nostrand Reinhold.
3. Clayton, G.D.; and Clayton, F.E., Editors. 1981. *Patty's Industrial Hygiene and Toxicology. Third Revised Edition. Volume 2A: Toxicology*. New York, New York: John Wiley & Sons, Inc.
4. Mølhave, L. 1982. "Indoor Air Pollution Due to Organic Gases and Vapours of Solvents in Building Materials." *Environ Int.* 8:117-127.

APPENDIX F: Sample Language for Contract Documents

Following is a sample of contract language used by the USEPA for their New Headquarters Project to specify indoor air quality requirements for office furniture systems. This contract does **not** represent official USEPA policy and it was developed for their New Headquarters furniture contract **only**. The contract language was developed with the cooperation of several furniture manufactures. Several manufacturers responded to the document when it was sent out for bid, and a furniture manufacturer was selected. Only the manufacturer that was selected was required to provide the information specified in this contract. We caution readers that the expense of the emissions testing specified in this sample contract is considerable (in the case of the USEPA contract this cost was about \$20,000) and that only a limited number of laboratories are capable of performing it. In addition, no standard testing methods exist for contacting chamber tests, quantifying TVOCs, or for specifying duration of a test. This document does not endorse or oppose the language listed below. Lettering and numbering of the text is that of the original document.

APPENDIX B:

EMISSIONS TESTING REQUIREMENTS - EPA's NEW HEADQUARTERS PROJECT: FURNITURE PROCUREMENT

I. INTRODUCTION

EPA is committed to providing their employees with a healthful, productive workplace. Providing good indoor air quality is central component of this commitment. Good indoor air quality is influenced by several integral factors:

- 1. Good HVAC system design/construction/maintenance*
- 2. Adequate ventilation with fresh air*
- 3. Adequate filtration*
- 4. Appropriate management of construction/remodeling work*
- 5. Source management*

The careful selection of materials is an important component of any source management strategy. Evaluating Volatile Organic Compound (VOC) emissions can improve building material/furnishing decision making.

II. EMISSION TESTING

There are no federal regulations governing VOC emissions from building materials. However, product manufacturers have begun to focus on limiting emissions of selected chemicals and have established testing programs for their products. Guidance for small chamber testing has been established (ASTM D 5116-90) and is being used by a number of product manufacturers to test their products in chambers.

In addition, the State of Washington in 1990 established emissions testing requirements for vendors interested in bidding on the State's furniture contract. This procurement required independent large chamber testing of an entire system under standardized test conditions.

Emission levels for TVOC's, formaldehyde and particulates were measured.

EPA's New Headquarters Project intends to establish an environmental large chamber testing protocol for emissions testing of workstations to be procured under this contract. A brief outline of the anticipated requirements is included below for your information.

IIIA. EPA's NEW HEADQUARTERS PROJECT SPECIFICATIONS FOR SYSTEMS FURNITURE

The EPA New Headquarters Project intends to establish emission standards for all workstations to be included under this contract. Testing protocols will be identified which will allow for standardized large chamber testing of a single composite workstation. This workstation is not a prototype for this procurement. It will include typical componentry to be used in a number of workstations which are being standardized to meet EPA's specific New Headquarters requirements. Testing for the following parameters will be undertaken:

- | | |
|------------------------|--|
| • TVOC's ¹ | <0.5 mg/m ³ |
| • Formaldehyde | <0.05 ppm |
| • Total Aldehydes | <0.1 ppm |
| • 4-PC (as an odorant) | below the limits of detection ² |

¹NOTE: TVOC's represents the sum of volatile organic compounds (VOC's) that can be analyzed and measured by the specified analytical method, and are calibrated referenced to toluene (by introducing known quantities of toluene onto a sorbent trap and introducing it into the analytical system exactly as a sample analysis would be).

²NOTE: The limit of detection is defined as the amount of the material (analyte) that can be distinguished from background, i.e., below the limits of detection means less than the quantitation limit of the analytical technique.

IIIB. In addition, and subsequent to this testing, EPA reserves the right to undertake small chamber testing, in accordance with ASTM D 5116-90, for items such as panel fabric (which could change over the period of the contract) and other components including new items which become available during the period of the contract.

IIIC. EPA also reserves the right to undertake discretionary testing of complete workstations at their own cost throughout the period of the contract. This is intended to ensure that the selected vendor's product continues to meet the established test standard. Should testing described in IIIB and IIIC produce results which exceed the accepted emissions standards, the vendor will be responsible for correction of the problem at his own cost.

IV. TEST PROTOCOLS

Environmental large chamber test protocols will use selected conditions representative of anticipated conditions at the new EPA headquarters complex. They will include the ventilation rate (ACH), product loading (m^2/m^3), (product loading is the ratio of the test specimen area to the chamber volume), humidity, and temperature. The environmental chamber testing will be conducted to the extent practicable in accordance with the guidance established for small chamber environmental testing (ASTM D 5116-90) and any up-dates to that document in place at the test date, together with modifications necessary to meet the requirements of large chamber testing.

Vendors who choose to submit a proposal for the forthcoming RFP, will be responsible for submitting the composite workstation components to the selected laboratory. Packaging of the componentry must be in accordance with the established protocol, details of which will be available to interested vendors. Schedule for delivery will be strictly enforced to ensure that the workstation components come directly from manufacturer's production line to the laboratory holding area, where they will be allowed to acclimatize for 24 hours prior to being assembled in the test chamber.

V. DURATION OF TEST & DOCUMENTATION

EPA believes that essential information can be gained by testing this composite workstation under the controlled conditions noted above for a maximum of seven days (168 hours). This period of time will allow for the identification of TVOCs, formaldehyde, total aldehydes, and 4-PC.

During this period sample collection for analysis of TVOCs, formaldehyde, total aldehydes and 4-PC will be made, starting at one hour after installation and continued at pre-determined intervals throughout the 168 hours of the test period.

Sample collection will be fully documented by lab personnel. A representative from the manufacturer may be present at the sample collection if desired.

VI. COSTS

All costs associated with the testing of the workstation will be borne by the manufacturer. (with the exception of any possible tests conducted by the EPA as noted above in section IIIC.) The costs include, but are not limited to, packaging of the componentry, transportation, assembly, all costs associated with laboratory procedures and lab time, disassembly, and transportation back to manufacturer.

Note: It is anticipated that laboratory costs will be substantially lessened due to the reduction in time from the more typical thirty-nine (39) days test period to seven (7) days. However, no cost data are available at the moment.

VII. COMPOSITE WORKSTATION

A Plan and an axonometric drawing of the composite workstation for the EPA procurement are included, together with a list of typical components required for the workstation (See Appendix C). All manufacturers wishing to submit an RFP in response to the forthcoming solicitation must be prepared to deliver a workstation for testing which meets these basic requirements. Only minor variations in dimensions and scope will be accepted. The workstation will remain the property of each manufacturer, and can be returned at vendor's expense on completion of the testing.

APPENDIX D:

ENVIRONMENTAL CHAMBER TESTING FOR FURNITURE, QUALITY ASSURANCE EMISSIONS TESTING PROCEDURES - EPA's New Headquarters Project

PART 1 - GENERAL

1.0 **WORK INCLUDED**

An indoor pollutant source management plan which will provide assurance that minimum pollutant emission rate standards for components and finish materials are met by applying uniform testing controls and procedures.

2.0 **PRODUCT(S) INCLUDED**

Product shall include a single, easily assembled, composite workstation, incorporating panels, components and related modular units, as developed for this protocol and which meets the requirements of EPA's New Headquarters Project. See Appendix C of the Requote for workstation layout and itemized list of componentry.

Fabric(s) shall be excluded from this testing procedure, and may be tested separately in accordance with ASTM Standard D5116-90.

PART 2 - PROTOCOL FOR SHIPPING FURNITURE TO CHAMBER TESTING LABORATORIES

3.0 **SELECTION PROCESS**

The furniture selected for testing should be taken directly off the production line. It should be representative of and treated no differently (including temperature and air flow) from other similar types of furniture. The furniture should be randomly selected. Neither the first nor the last piece in a production batch should be selected. The furniture should not be selected based on any physical attribute that distinguishes it from the other furniture in the batch. The furniture will be selected in the presence of an EPA official or his or her representative.

3.1 **PACKAGE PROTOCOL**

The furniture should be shrink-wrapped directly off the production line, consistent with the Manufacturer's standard practice. An unused sample of the packing material must be included with each shipment.

3.2 **SHIPPING & LABELING**

The furniture should be shipped to arrive at the chamber testing laboratory within 48 hours of manufacture. Each piece should be labeled (see example below) with the date, and time of manufacture and shipping to enable the testing laboratory to place the furniture in the chamber at the appropriate time.

SAMPLE FURNITURE LABEL

Date and Time of Manufacture:

Date and Time of Shipping:

Shipping Company:

Furniture Company:

Furniture Description (e.g., Make and Model):

Signature of Furniture Company Employee:

Because the workstation must be placed in the chamber within 48 hours of arrival at the chamber testing laboratory, the manufacturer should coordinate the schedule for arrival of all pieces of the workstation with the chamber testing laboratory.

PART 3 - EXECUTION

4.0 TARGET POLLUTANT EMISSION RATES

The target emission standards are defined as those "emission rates" of pollutants emanating from the product of concern which will not produce building air concentrations greater than the following:

- | | |
|---------------------------------|--------------------------------------|
| <i>(a) Formaldehyde</i> | <i><0.05 ppm</i> |
| <i>(b) TVOC's</i> | <i><0.5 mg/m³</i> |
| <i>(c) Total Aldehydes</i> | <i><0.1 ppm</i> |
| <i>(d) 4-PC (as an odorant)</i> | <i>below the limits of detection</i> |

The pollutant specification compliance is based on an outside air rate of 1.0 A.C.H. The loading rate is 1 full workstation per 25.7 m³. A workstation is defined in 2.0 above.

5.0 TEST PROTOCOLS

The environmental chamber testing will be conducted to the extent practicable in accordance with the guidelines established for small chamber environmental testing (ASTM D 5116-90) and any updates to that document in place at the test date, together with modifications necessary to meet the requirements of large chamber environmental testing.

All data shall be made available for review by EPA's New Headquarters planning staff and their consultants.

Specific requirements for this protocol include, but are not limited to the following parameters, in addition to those noted above.

- (a) The tests shall be conducted in a chamber capable of accommodating the entire workstation as specified by EPA (See Appendix C). The range of chamber sizes which may be used is 21 to 29 m³. The volume of air that flows through the chamber will be at a constant volume of 25.7 m³/hr.*
- (b) The environmental chamber will be constructed of inert, smooth surfaces such as stainless steel or glass and will assure that formaldehyde at the level of 0.05 ppm and representative volatile organics at the level of 10 ug/m³ are not irreversibly retained on the interior of the surfaces. Quality control data must be submitted showing that recovery rates of 85-115% are possible for formaldehyde, toluene, and decane at these levels, as per the recoveries specified by the analytical method.*
- (c) The air within the chamber will be free of any obstructions or contamination such as internally mounted fan(s), humidifiers, or refrigeration coils. A fan with an external mounting may be used to keep the chamber air well mixed. The internal air will only come in contact with inert chamber walls, a fan with an external mounting, the air diffusion system and sampling ports.*
- (d) Internal air velocity within the chamber will be reproducibly maintained at a level in the range of 0.05 to 0.1 m/sec. (10 to 20 fpm).*
- (e) Internal chamber air will be well mixed and comply with 5% of the theoretical well-mixed model.*
- (f) Clean air will be generated and used as the supply air to the chamber. It is necessary that the supply air backgrounds be sufficiently low to achieve statistically meaningful analytical measurements at the level anticipated. Purified air will be supplied to the chamber with background concentrations not exceeding 0.002 ppm formaldehyde, and 2 ug/m³ of total volatile organics with no individual organic exceeding this level. The ambient air (background) in the chamber should also not exceed these levels. Using gas chromatographic thermal desorption/mass spectrometric technique, the ambient air in the chamber will be sampled just prior to loading.*
- (g) The chamber operation will be maintained with strict and reproducible operating parameters of 1.0 ± 0.05 A.C.H., 25° ± 2° C and 50% ± 5% relative humidity. These parameters shall be monitored continuously throughout the test, and shall be included in the final report.*
- (h) The chamber will be operated under slight positive pressure relative to atmospheric pressure.*
- (i) The test protocol will include evaluation of pollutant emissions over a nominal one (1) week, 7 day period (± four (4) hours) to allow for mathematical modeling of the product emission profiles over time. Operational and QC procedures will be adequate to maintain sample integrity over the entire test period.*

- (j) *Off-the-line products (workstation components) are to arrive at the testing laboratory with 48 hours of the testing date. The materials are to remain in their packaged state until immediately prior to loading into the environmental chamber. (The product selection, packaging, and shipping protocols are described in Part 2, items 3.0-3.2.) The components are to be unpacked immediately prior to assembly and set-up in the environmental chamber. Care must be taken during assembly by the installers, in concert with the laboratory personnel, not to introduce any contamination into the chamber. The testing facility must have a QC procedure to minimize this concern. Testing of the pollutant levels must begin following one (1) hour of complete installation and enclosure in the environmental chamber.*
- (k) *Emission rates are to be determined from the environmental chamber measurements.*
- (l) *Dynamic analytical measurements will be made using methods sensitive and reproducible at the level in the low ppb range and other volatile organics. Appropriate standard and recovery data will be obtained for the classes of compounds and the concentration ranges found to substantiate the accuracy and precision of the analytical methods used.*
- (m) *Analysis of air samples for formaldehyde, TVOC's (total volatile organic compounds), total aldehydes, and 4 phenylcyclohexene are to be reported separately.*
- (n) *Quality control data on the chamber operational parameters as mentioned in Section 5.0, Test Protocols, items (a) through (f) above must be submitted with the final analytical data, as well as supporting documentation for the accuracy and precision of the analytical measurements. A statistically valid number of analytical measurements must be made for interpretative reasons, and external quality control audits must be incorporated into the overall measurements program.*

5.1 SAMPLE COLLECTION AND ANALYSIS

- (a) *Timing for sample collection for analysis for formaldehyde, TVOC's, total aldehydes and 4-PC; 1 hour after workstation assembly and enclosure in the chamber, and then at 4, 24, 72, 120, and 168 hours thereafter.*
- (b) *Air samples are to be analyzed and measured utilizing the specified analytic method and are to be calibrated referenced to toluene or other suitable analytical standards. (Air samples to be collected on multi-sorbent trap and analyzed by gas-chromatography-mass spectroscopy.)*

5.2 AIR EXCHANGE RATE

Air exchange rate in chamber: 1.0 air changes per hour (ACH) of clean air for a 25.7 m³ chamber, or an equivalent ACH for a different size chamber (see Section 5.0, Test Protocols, item (a) for acceptable sizes). Air flow through chamber: use a one-pass system using clean purified air as referenced in 5.0 (f).

5.3 AIR VELOCITY

Air velocity within the chamber will simulate the building environment. Velocity as described in 5.0 (d) is required and must be verified upon completion of chamber test. Mixing shall be provided for by careful location of inlets and outlets for air supply and circulation. The report or the tests shall include a description of the airflow in the chamber. The report or the tests shall include a distribution of the air flow in the chamber and the determination of distribution patterns, mixing and local velocity at the surfaces of the test specimen. Local velocity shall be measured 1 cm. from specimen surfaces at no less than five representative locations.

5.4 QUALITY ASSURANCE/QUALITY CONTROL

Report of test must include complete description of the test system, analysis and results. All Quality Assurance/Quality Control (QA/QC) procedures must be reported.

5.5 REPRESENTATION AT TESTING LABORATORY

As its own cost, the manufacturer may choose to have a company representative present during the sample collection and analysis. This will be an observatory role. All work connected with the testing will be handled by lab personnel.

PART 4 - ADDITIONAL TESTING

6.0 MANUFACTURER RESPONSIBILITY

If, after installation of the product, a strong odor is detected, EPA may request a random sample/component of the workstation be retested. The manufacturer shall bear responsibility for retesting the suspect component in an appropriately sized chamber test to verify the system meets the emissions testing requirements for EPA's New Headquarters Project. If the suspect component does not meet the specified requirements, the Manufacturer shall replace the component throughout with one which does meet the emissions testing requirements for EPA's New Headquarters Project, at no cost to EPA.

6.1 EPA's TESTING OPTION

At any time during the manufacture of componentry designated for the new EPA Headquarters Project, and/or during installation or thereafter, EPA reserved the right to undertake discretionary testing of individual components and/or a complete workstation (excluding fabric) at their own cost. Should such testing produce results which exceed the accepted emission standards as established by this protocol, the manufacturer shall be responsible for replacing the components or workstations throughout the project with replacement(s) which meet the emissions testing requirements for EPA's New Headquarters Project, at no cost to EPA.

**ENVIRONMENTAL CHAMBER TESTING FOR FURNITURE -
EPA's New Headquarters Project**

ADDENDUM TO REQUOTE: SYSTEMS FURNITURE

Ref: Appendices B, C, and D

Attached, please find the name, address, and contact personnel together with fax and telephone numbers for the three (3) testing laboratories EPA has identified as acceptable for the independent large chamber testing of vendors' systems furniture. The systems furniture will include all items described in Appendix C together with essential hardware, etc., necessary to assemble the composite workstation. Testing will be undertaken in accordance with the protocol outlined in Appendix D of the Requote.

Please note that the time allowed for shipping the furniture from the factory to the testing laboratory is 48 hours. However, the holding time at the laboratory, prior to assembly in the test chamber has been increased from 24 hours (as described in Appendix B) to 48 hours.

Vendors may select any of the three laboratories listed. Other independent laboratories may also be acceptable to EPA. Should a vendor wish to utilize a laboratory other than those listed, the name, contact person, and telephone number should be submitted in writing to Mr. Jeffrey L. Davidson at EPA's Safety, Health and Environmental Management Division for approval prior to proceeding with any such arrangements.

The tentative schedule for testing the systems furniture has been set for mid-November, 1995. However, final arrangements will have to be made by the vendor(s) after the technical and cost review process is complete, and an actual date can be established for the total testing process.

APPENDIX G: Survey of Testing Methods for VOCs

Several standard guides, practices, and methods exist for testing building materials. In addition, a number of proposed standards and guidelines are being considered both in the United States (under the direction of the ASTM) and in Europe [under the framework of the European Collaborative Action (ECA): Indoor Air Quality and its Impact on Man].

G1 American Society for Testing and Materials (ASTM)

- a) ASTM D 3960 - 93: *Standard Practice for Determining Volatile Organic Compound Content of Paints and Related Coatings*;
- b) ASTM D 5116 - 90: *Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products*;
- c) ASTM E 1333 - 90: *Standard Test Method for Determining Formaldehyde Levels from Pressed Wood Products Under Defined Test Conditions Using a Large Chamber*; and
- d) ASTM D 3614 - 90: *Guide for Laboratories Engaged in Sampling and Analysis of Atmospheres and Emissions*.

G2 Canadian General Standards Board (CGSB)

CAN/CGSB-51.23-92: *Spray-applied rigid polyurethane cellular thermal insulation*.

G3 Commission of the European Community (CEC)

- a) EUR 13593-1991: *Guideline for the Characterization of Volatile Organic Compounds Emitted from Indoor Materials and Products Using Small Test Chambers*; and
- b) EUR 12196-1989: *Formaldehyde Emission from Wood Based Materials: Guideline for the Establishment of Steady State Concentrations in Test Chambers*.

G4 Nordic Countries: Nordtest Methods (NT)

NT Build 358: *Building Materials: Emissions of Volatile Compounds, Field and Laboratory Emission Cell (FLEC)*. This method is also described in Wolkoff et al. (1991) and Gustafsson and Jonsson (1993),

G5 Swedish National Testing and Research Institute and Swedish National Flooring Trade Association

The standards listed below are described in Gustafsson and Jonsson (1993):

- a) Trade Standard: *Measurement of Chemical Emission from Flooring Materials*; and
- b) Trade Standard: *Measurement of Chemical Emission from Smoothing Compounds*.

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

APPENDIX H: California Regulations for Architectural Coatings and Consumer Products

In California, architects, contractors, building owners and managers must comply with three product-related regulatory programs when building, renovating, and maintaining buildings. These programs effectively limit emissions of reactive organic gases from architectural coatings and consumer products. Reactive organic gases are VOCs that are photochemically reactive and contribute to the formation of ground level ozone (smog). (The complete definition of reactive VOCs is shown in the glossary at the end of this document.) These programs are important components of the California Air Resources Board's (CARB's) mission to protect public health from the adverse effects of air pollutants.

Architectural coatings regulations limit VOC content in coatings such as paints, varnishes, and wood preservatives. These regulations have been adopted by a number of local air pollution control districts (APCDs) and air quality management districts (AQMDs) in California, with oversight by the CARB. Two other regulations limit VOC content in products sold throughout California, and are managed by the CARB: (a) the Aerosol Coatings Products Regulation limits VOC emissions in a variety of aerosol coating products such as aerosol paints, wood stains, and clear coating products; and (b) the Consumer Products Regulation limits VOC content in several types of consumer products, which include both household products and certain products commonly used in institutional and industrial maintenance or operations. A side benefit of these regulations may be reduced VOC levels in indoor air when regulated products are used inside building structures.

H1 Architectural Coatings

Architectural coatings are coatings applied to stationary structures and their appurtenances, to mobile homes, to pavements, or to curbs. These products include both water-based and solvent-based coatings such as flat or higher gloss paints, lacquers, varnishes, metallic pigmented coatings, primers, sealers, concrete curing compounds, and below ground wood preservatives. Architectural coatings are a source of VOC emissions to both indoor and outdoor environments.

Architectural coatings in many regions of California now have lower VOC contents than coatings that are available in other parts of the United States. In 1989, the CARB developed a suggested control measure (SCM) on architectural coatings for possible adoption by the APCDs and AQMDs (ARB-CAPCOA, 1989). The SCM, which was based primarily on previous model rules, presents proposed standards stipulating the allowable content, by weight, of total VOCs for each type of coating (see Table H1). Regulations based on the SCM and previous model rules have been adopted by 16 of the 34 districts in California.

In districts where there is an architectural coatings regulation, it is illegal to solicit the use of, or to sell, non-complying coatings. For example, clients in districts where architectural coating rules have been adopted may not request the use of non-complying coatings by their architect, contractor, or building manager. Before selecting products to be used in building or renovating a particular building, architects, contractors, and building managers should consult the local APCD or AQMD if they have any questions about compliance with local architectural coating regulations (see Section K6 of Appendix K for a list of California's air pollution control districts). In particular, contractors and others should check with the local APCD or AQMD if they are purchasing coating supplies from outside the district in which the building project is located.

Based on 1990 data, the CARB estimates that 39,100 tons of VOCs are released into the air each year from architectural coatings (CARB, 1994b). Although about three-quarters of all coating sales in California are water-based paints, solvent-based coatings produce more than twice the amount of VOC

emissions as water-based coatings. Solvent-based coatings produce an estimated 26,181 tons of VOCs per year. The CARB estimates that adoption of the SCM by the districts would achieve a reduction of 4,841 to 7,887 tons of VOCs per year from solvent-based coatings (CARB, 1994b).

H2 Aerosol Paints

Aerosol coating products such as paints, stains, and clear coatings packaged in disposable cans emit a significant amount of VOCs to the air during use. The CARB estimates that 30 tons of VOCs per day are emitted to the air from these products (CARB, 1995a). The CARB is required by Section 41712 of the California Health and Safety Code to develop regulations controlling emissions of VOCs from aerosol coating products.

The CARB adopted a regulation, which became effective on January 8, 1996, that reduces VOC content in aerosol coating products. This regulation sets VOC standards for a variety of aerosol paint products, such as flat and glossy paints, primers, metallic coatings, wood stains, clear coatings, and other coatings (CARB, 1995a). There are two tiers of this regulation, the first effective January 8, 1996, and the second effective December 31, 1999. By each effective date, manufacturers must produce aerosol products for sale in California that comply with maximum allowable VOC content limits (see Table H2). Suppliers may continue to sell the older non-complying aerosol products for 18 months after each effective date.

CARB staff projected a 12 percent reduction (about a 3 tons per day reduction) in VOC emissions from the adoption of the first tier of this regulation (CARB, 1995a). However, the recent exemption of acetone as a reactive VOC has significantly reduced this estimate. CARB staff project reductions of about 60 percent (about an 18 tons per day reduction) when the second tier standards become effective (ibid). This regulation is effective statewide, with the exception of the Bay Area Air Quality Management District (BAAQMD), which adopted an aerosol paint rule in 1990.

H3 Consumer Products

The CARB adopted a regulation to limit the amount of VOCs in selected consumer product categories in 1990 (Phase I), and amended the regulation to include additional products in 1992 (Phase II). These categories include detergents, cleaning compounds, polishes, floor finishes, disinfectants, sanitizers, and certain insecticides that are likely to be used in building cleaning and maintenance activities before and after construction. Such products sold in California must adhere to the maximum allowable VOC limits shown in Table H3.

For further information on regulations pertaining to architectural coatings, aerosol coating products, and consumer products, interested parties may call the CARB at (916) 322-2990.

H4 References

Section K8.3 of Appendix K lists all the publications referenced here and presents a brief summary of the contents of each publication. Exact citations are also provided in the References section at the end of this document.

Table H1. Selected Architectural Coating Standards * From California's Suggested Control Measure (ARB-CAPCOA, 1989)		
Coating Category		Maximum Allowable Grams of Reactive VOCs per Liter
Below ground wood preservatives		350
Bond breakers		350
Clear wood finishes	Lacquer	680
	Sanding sealers	350
	Varnish	350
Concrete curing compounds		350
Dry fog coatings		400
Fire-retardant coatings	Clear	650
	Pigmented	350
Form-release compounds		250
Graphic arts (sign) coatings		500
Magnesite cement coatings		450
Mastic texture coatings		300
Metallic pigmented coatings		500
Multi-color coatings		420
Opaque stains		350
Opaque wood preservatives		350
Pre-treatment wash primers		420
Primers, sealers and undercoaters		350
Semi-transparent stains		350
Semi-transparent and clear wood preservatives		350
Shellac	Clear	730
	Pigmented	550
Waterproofing sealers		400

^a This is a partial listing of standards presented in *ARB-CAPCOA Suggested Control Measure for Architectural Coatings* (ARB-CAPCOA, 1989). The suggested control measure is a model rule developed by the CARB. Each district may adopt all, part, or none of these standards, or may adopt different rules. The reader is encouraged to consult with their local air pollution control districts for specific architectural coating standards.

Table H2. Selected Aerosol Coating Standards * in California (CARB, 1995b)				
Aerosol Coating Category			Maximum Allowable Percent of Reactive VOCs by Weight	
			Effective 1/8/96	Effective 12/31/99
General coatings	Clear coatings		67	40
	Flat paint products		60	30
	Fluorescent coatings		75	45
	Metallic coatings		80	50
	Nonflat paint products		65	30
	Primers		60	30
Specialty Coatings	Glass coatings		95	80
	Shellac Sealers	Clear	88	70
		Pigmented	75	60
	Slip-resistant coatings		80	70
	Spatter/Multicolor coatings		80	60
	Vinyl/fabric/leather/ polycarbonates		95	70
	Webbing/veil coatings		90	70
	Weld-through primers		75	60
	Wood stains		95	75
	Wood touch- up/repair/restoration		95	75

^a Adopted January 8, 1996 with the exception of the Bay Area Air Quality Management District which adopted a similar rule in 1990.

Table H3. Selected Consumer Product Standards in California (CARB, 1993a)			
Product Category		Percent of Reactive VOCs by Weight	
		Current ^a	Future
Air Fresheners	Single phase aerosols	30	
	Double phase aerosols	30	
	Liquids/pump sprays	18	
	Solids/gels	3	
	Dual purpose air fresheners/disinfectant aerosols	60	
Bathroom & Tile Cleaners	Aerosols	7	
	All other forms	5	
Floor Polishes/Waxes	Products for flexible flooring materials	7	
	Products for nonresilient flooring	10	
	Wood floor wax	90	
Furniture Maintenance Products	Aerosols	25	
	All other forms except solid or paste forms	7	
General purpose cleaners		10	
Glass Cleaners	Aerosols	12	
	All other forms	6	
Dusting Aids	Aerosol	35	25 (1/1/97)
	All other forms	7	
Fabric protectants		75	60 (1/1/97)
Household Adhesives	Aerosol	75	25 (1/1/97)
	Contact	80	
	Construction & panel	40	
	General purpose	10	
Insecticides	Crawling bug	40	20 (1/1/98)
	Flying bug	35	
	Foggers	45	

^a As of 5/31/96

APPENDIX I: Estimating Indoor Concentrations From Emission Factors

I1 Using Mass Balance Equations to Predict Indoor VOC Concentrations

In theory, prediction of pollutant concentrations in indoor environments using mathematical models has an attractive advantage: estimations of occupant exposure to various indoor pollutants can be made prior to building construction and based on emission data of the building materials, building ventilation rates, and the sink effects of some of these materials. In addition, the effectiveness of various control strategies, such as increased ventilation, can be estimated and their costs justified to building owners at least based on simple theoretical terms.

In practice, the use of such models is problematic. Mathematical models are based on mass balance equations for each pollutant. A mass balance equation simply states that the rate of change of the mass of a pollutant in an indoor environment is equal to the difference between the pollutant mass entering the indoor environment and the total pollutant mass exiting that environment. However, the mass balance modeling approach is complicated because all terms of a mass balance equation are time and space dependent. For example, the VOC emission rate of a building material may vary with time; indoor VOC concentrations may not be distributed uniformly throughout a building; airflow rates into a building or a space may vary with time, such as in the case of VAV systems; and the removal rate of VOCs may vary with time, such as in the case of a porous surface with its absorptivity varying according to the amount of pollutant load. It is beyond the scope of the guidelines presented in this document to discuss complex mathematical models. Instead, the interested reader is referred to: (a) the USEPA Indoor Air Quality Model as described in Sparks et al. (1989, 1991), Sparks and Tucker (1990), and Owen et al. (1989); and to the NSIT model as described in Walton (1994).

Simple equations can be derived from complex mass balance models after a number of assumptions are made. These simple equations can be used for estimating ranges of VOC concentrations. Such assumptions include:

- a) VOC emission rates are constant;
- b) airflow rates do not vary with time;
- c) there are no VOC removal mechanisms other than ventilation (i.e., no filtration, no adsorption onto surfaces, and no chemical decomposition); and
- d) perfect mixing.

I1.1 A Simplified Mass Balance Equation for Calculating Indoor VOC Concentrations

One of the simplest forms of a mass balance equation is the steady-state equation. A steady-state equation is applicable only when the concentration of a pollutant in an indoor environment has reached steady-state conditions (i.e., concentrations are no longer time dependent). Nielsen et al. (1994) recommended the following first order mass-balance equation for calculating indoor concentrations of VOCs emitted from building materials and products:

$$C_{ss} = \frac{EF \cdot A}{N \cdot V} \quad (I1)$$

where:

C_{ss}	=	calculated equilibrium concentration of a chemical compound in the indoor air ($\mu\text{g}/\text{m}^3$)
N	=	air change rate, (ACH or 1/h)
V	=	volume of the indoor environment (m^3)
EF	=	emission factor of the chemical compound from the material or product ($\mu\text{g}/\text{m}^2\cdot\text{hr}$)
A	=	area of the material or product in the indoor environment (m^2).

The ratio A/V is termed a material's **loading factor or ratio**. The loading factor can be calculated using Equation I2.

$$L = \frac{A_m}{A_f \cdot H} \quad (12)$$

where:

L	=	loading factor (m^2/m^3)
A_m	=	area of installed material (m^2)
A_f	=	floor area of indoor space where material is installed (m^2)
H	=	ceiling height of indoor space where material is installed (m)

Equation I1 can be rewritten using the above definition of the loading factor:

$$C_{ss} = \frac{EF}{N} \cdot L \quad (13)$$

Equation I3 simply states that the indoor concentration of a given chemical compound is equal to its source strength (expressed in $\mu\text{g}/\text{m}^2\cdot\text{hr}$) multiplied by the loading factor of the material emitting the chemical compound (expressed in m^2/m^3), and divided by the building ventilation rate (expressed in 1/hr).

Equation I3 can be used to estimate indoor concentrations of VOCs based on emission factors of building materials and products, loading factors, and building ventilation rates. The estimated indoor concentrations can be used to select building materials and products by comparing these concentrations to the guidelines listed in Appendix E. Calculation of indoor concentrations of VOCs is made only for the purpose of selecting building materials and products and not for precise prediction of indoor concentrations after a building has been constructed. This is because some of the assumptions associated with the steady-state equation do not hold true in the "real" world.

When comparing calculated VOC concentrations with health-based VOC guidelines, it is important to recognize that emission factors of installed materials may be different from the factors measured in chamber tests due to differences in environmental conditions, manufacturing processes, or age.

I2 Examples of Application of the Steady-State Equation

The following examples illustrate the application of Equation I3 in estimating indoor concentrations from emission factors.

I2.1 Example 1: Application of the Steady-State Equation in the Selection of a Carpet

Carpets are considered "dry" products emitting VOCs at moderate to low rates for weeks or months after manufacturing and installation.

Table I1 lists TVOC emissions factors for four carpet samples.

Table I1. TVOC Emission Factors Of Four Carpet Samples ($\mu\text{g}/\text{m}^2\cdot\text{hr}$)^a						
Carpet	Description of Backing			Age	TVOC Emission Factor ($\mu\text{g}/\text{m}^2\cdot\text{hr}$)	
	Primary	Secondary	Adhesive		24 hr	168 hr
1a	Polypropylene	Polypropylene	SBS latex	2 wks	213	71
1b				5 wks	178	51
2	Polypropylene	Polyurethane	not specified by the manufacturer	2 wks	83	33
3	Polypropylene	Polyvinyl chloride		3 wks	602	192
4	Polypropylene	Polypropylene	SBR latex	2 wks	399	94

^a Reference: Hodgson et al. (1993).

Storage age (i.e., not installed age); samples were kept in Tedlar® bags from the time of manufacture until they were tested; decreases in emissions during storage were minimal.

The CRI's maximum allowable TVOC emission factor for carpets is currently $500 \mu\text{g}/\text{m}^2\cdot\text{hr}$ at 24 hr after manufacture (see Appendix C). In addition as shown in Table E1 (Appendix E), Tucker's maximum emission factor for flooring materials is $600 \mu\text{g}/\text{m}^2\cdot\text{hr}$. All carpet samples meet the recommended factors except for Carpet Sample 3 at 24 hr. However, the reader is reminded that: (a) TVOC measurements have high uncertainties due to variations in the mixture of compounds; and (b) there can be differences of two or more times in TVOC results depending on the measurement and analysis methods.

To calculate TVOC concentrations, we first assume 100 percent floor area coverage (i.e., $A_m=A_f$) and a ceiling height of 2.5 m (~8 ft). Then from Equation I2, we calculate the loading factor to be $0.4 \text{ m}^2/\text{m}^3$. Using Equation I3, we can calculate the resulting C_{ss} for various ventilation rates. Table I2 shows the results of these calculations.

The above calculated TVOC concentrations can be compared to those listed in Appendix E (Section E1). If we consider the State of Washington's (Section E1.3) TVOC guideline of $500 \mu\text{g}/\text{m}^3$ and assume that no adhesive or padding will be used during carpet installation, then we conclude that all carpet samples meet this recommendation with Carpet Sample 2 having the lowest TVOC concentrations. It is noted that the indoor TVOC concentration of Carpet Sample 3 at 24 hr and at the low ventilation rate (i.e., 0.5 ACH) is only slightly below this recommendation. However increasing the ventilation rate to 1.0 ACH lowers this concentration by 50%.

Table I2. Calculated Indoor TVOC Concentrations ($\mu\text{g}/\text{m}^3$) of Four Carpet Samples Based on a Loading Factor of $0.4 \text{ m}^2/\text{m}^3$						
Carpet	ACH = 0.5		ACH = 1.0		ACH = 4.0	
	24 hr	168 hr	24 hr	168 hr	24 hr	168 hr
1a	170	57	85	28	21	7.1
1b	140	41	71	20	18	5.1
2	66	26	33	13	8.3	3.3
3	480	150	240	77	60	19
4	320	75	160	38	40	9.4

The above example illustrates the following:

- a) the lower the TVOC emission factors the lower the indoor TVOC concentrations; and
- b) increased ventilation rates result in decreased estimated indoor TVOC concentrations.

I2.2 Example 2: Application of the Steady-State Equation in the Selection of a Carpet Adhesive

Adhesives are considered "wet" products that typically emit solvents and other chemicals at relatively high rates for a few hours or days after installation.

Table I3 lists emissions data for three different carpet adhesives tested at 24 and 144 hr (i.e., six days) in an environmental chamber. Note that the adhesives were tested individually and not as part of a complete carpet system consisting of carpet, cushion, glue, etc. Adhesives tested individually may not behave the same as in a complete carpet system.

Table I3. TVOC Emission Factors Of Three Adhesives ($\mu\text{g}/\text{m}^2\cdot\text{hr}$) ^a			
Adhesive	Description	TVOC Emission Factor ($\mu\text{g}/\text{m}^2\cdot\text{hr}$)	
		24 hr	144 hr
1	Multipurpose latex adhesive	99,000	17,200
2	Multipurpose latex adhesive	76,000	3,950
3	Synthetic, "low-VOC" adhesive	698	76

^a Reference: Black et al., 1991b

It is worth noting that although at 24 hr the emission factor of Adhesives 1 and 2 differ only by about 23 percent, at 144 hr their emission factors differ by a factor of four. This observation illustrates the difference in the long-term emission rates of various adhesives and the importance of using long-term emission data for product comparison and selection. It is also worth noting that Adhesive 3 had a 100-fold

lower emission factor than the other two adhesives. If we use Tucker's maximum emission factor of $600 \mu\text{g}/\text{m}^2\cdot\text{hr}$ for flooring materials (Table E1 of Appendix E), then we should consider the emission factor of the complete carpet assembly (i.e., carpet and padding). Adhesives 1 and 2 exceed the $600 \mu\text{g}/\text{m}^2$ maximum emission factor at 144 hr even without accounting for emissions from the carpet or the padding. Even the low-emitting Adhesive 3 exceeds this maximum at 24 hr, but drops well below it at 144 hr.

Table I4 shows the resulting indoor VOC concentrations calculated using Equation I3 for various ventilation rates.

Table I4. Calculated Indoor TVOC Concentrations ($\mu\text{g}/\text{m}^3$) of Three Adhesives Based on a Loading Factor of $0.4\text{m}^2/\text{m}^3$						
Adhesive	ACH = 0.5		ACH = 1.0		ACH = 4.0	
	24 hr	144 hr	24 hr	144 hr	24 hr	144 hr
1	79,000	14,000	40,000	6,900	9,900	1,700
2	61,000	3,200	31,000	1,600	7,600	400
3	560	61	280	30	70	7.6

Using the State of Washington's (Section E1.3 of Appendix E) of $500 \mu\text{g}/\text{m}^3$ we conclude that:

(a) Adhesives 1 and 2 do not meet this recommendation at ventilation rates of 0.5, 1.0, or 4.0 ACH with the exception of Adhesive 2 at 4.0 ACH and 144 hr; and (b) Adhesive 3 meets this recommendation under all conditions except at 0.5 ACH and 24 hr.

The above example demonstrate again the points outlined at the end of Section I2.1 (Example 1), i.e., that indoor VOC concentrations can be reduced by selecting building materials with low VOC emission rates and by increasing building ventilation rates.

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

APPENDIX J: California's Minimum Ventilation Standard

California Code of Regulations, Title 8: Industrial Relations, Section 5142:

Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Ventilation

(a) Operation:

(1) The HVAC system shall be maintained and operated to provide at least the quantity of outdoor air required by the State Building Standards Code, Title 24, Part 2, California Administrative Code, in effect at the time the building permit was issued.

(2) The HVAC system shall be operated continuously during working hours except:

(A) during scheduled maintenance and emergency repairs;

(B) during periods not exceeding a total of 90 hours per calendar year when a serving electric utility by contractual arrangement requests its customers to decrease electrical power demand; or

(C) during periods for which the employer can demonstrate that the quantity of outdoor air supplied by nonmechanical means meets the outdoor air supply rate required by (a)(1) of this section. The employer must have available a record of calculations and/or measurements substantiating that the required outdoor air supply rate is satisfied by infiltration and/or by a nonmechanically driven outdoor air supply system.

(b) Inspection and Maintenance:

(1) The HVAC system shall be inspected at least annually, and problems found during these inspections shall be corrected within a reasonable time.

(2) Inspections and maintenance of the HVAC system shall be documented in writing. The employer shall record the name of the individual(s) inspecting and/or maintaining the system, the date of the inspection and/or maintenance, and the specific findings and actions taken. The employer shall ensure that such records are retained for at least five years.

(3) The employer shall make all records required by this section available for examination and copying, within 48 hours of a request, to any authorized representative of the Division (as defined in Section 3207), to any employee of the employer affected by this section, and to any designated representative of said employee of the employer affected by this section.

NOTE: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

HISTORY:

1. New section filed 1-8-87; effective thirtieth day thereafter (Register 87, No. 2). For history of former section, see Register 75, No. 29.

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

APPENDIX K: Information Resources

K1 Building Management Associations

Association of Physical Plant
Administrators of Universities and
Colleges
1446 Duke Street
Alexandria, VA 22314-3492
(703) 684-1446

Business Council on Indoor Air
2000 L Street, N.W., Suite 730
Washington, DC 20036
(202) 775-5887

Building Owners and Managers
Association
1201 New York Avenue, N.W., Suite 300
Washington, DC 20003
(202) 408-2662

Building Owners and Managers
Association of California
c/o Mr. Les Spahnn
Time - Noack - Kelly - Spahnn
770 L Street - Suite 960
Sacramento, CA 95814
(916) 442-4584

Institute of Real Estate Management
430 North Michigan Avenue
Chicago, IL 60611
(312) 661-1930

International Council of Shopping Centers
1199 North Fairfax Street, Suite 204
Alexandria, VA 22314
(703) 549-7404

International Facilities Management
Association
1 East Greenway Plaza, 11th Floor
Houston, TX 77046
(713) 623-4362

National Apartment Association
1111 14th Street, N.W., Suite 900
Washington, DC 20005
(202) 842-4050

National Association of Industrial
and Office Parks
1215 Jefferson Davis Highway, Suite 100
Arlington, VA 22202
(703) 979-3400

K2 Professional and Standard-Setting Organizations

Air and Waste Management Association
(A&WMA)
P. O. Box 2861
Pittsburgh, PA 15230
(412) 232-3444

Air-Conditioning and Refrigeration
Institute (ARI)
1501 Wilson Boulevard, Suite 600
Arlington, VA 22209
(703) 524-8800

American Conference of Governmental
Industrial Hygienists (ACGIH)
Kemper Woods Center
1330 Kemper Meadow Drive
Cincinnati, OH 45240
(513) 742-2020

American Industrial Hygiene Association
(AIHA)
2700 Prospect Avenue, Suite 250
Fairfax, VA 22031
(703) 849-8888

American Institute of Architects (AIA)
1735 New York Avenue, N.W.
Washington, DC 20006
(202) 626-7300

American Society of Heating,
Refrigerating, and Air-Conditioning
Engineers (ASHRAE)
1791 Tullie Circle, N.E.
Atlanta, GA 30329
(404) 636-8400

American Society for Testing and
Materials (ASTM)
Subcommittee D22
1916 Race Street
Philadelphia, PA 19103
(215) 299-5524

American Society of Safety Engineers
(ASSE)
1800 E. Oakton Street
Des Plaines, IL 60018-2187
(708) 692-4121

Association of Energy Engineers (AEE)
4025 Pleasantdale Road, Suite 420
Atlanta, GA 30340
(404) 447-5083

National Asbestos Council (NAC)/
The Environmental Information
Association
1777 Northeast Expressway, Suite 150
Atlanta, GA 30329
(404) 633-2622

National Conference of States on Building
Codes and Standards, Inc. (NCSBCS)
505 Huntmar Park Drive, Suite 210
Herndon, VA 22070
(703) 437-0100

National Society of Professional Engineers
(NSPE)
1420 King Street
Alexandria, VA 22314
(703) 684-2810

K3 Product Manufacturers

Adhesive and Sealant Council
1627 K Street, N.W., Suite 1000
Washington, DC 20006
(202) 452-1500

American Plywood Association/
Technical Services Division (APA)
P.O. Box 11700
Tacoma, WA 98411
(206) 565-6600

Asbestos Information Association
1745 Jefferson Davis Highway, Room 509
Arlington, VA 22202
(703) 412-1150

Association of Home Appliance
Manufacturers (AHAM)
20 N. Wacker Drive
Chicago, IL 60606
(312) 984-5800

Association of Wall and Ceiling Industries
307 E. Annandale Road, Suite 200
Falls Church, VA 22042
(703) 534-8300

Carpet Cushion Council
P.O. Box 546
Riverside, CT 06878
(203) 637-1312

Carpet and Rug Institute (CRI)
P.O. Box 2048
Dalton, GA 30722
(706) 278-3176

Chemical Specialties Manufacturers
Association
1913 Eye "I" Street, N.W.
Washington, DC 20006
(202) 872-8110

Foundation of Wall and Ceiling Industries
(FWCI)
307 E. Annandale Road, Suite 200
Falls Church, VA 22042
(703) 534-8300

Gas Appliance Manufacturers Association,
Inc. (GAMA)
1901 North Moore Street, Suite 1100
Arlington, VA 22209
(703) 525-9565

Hardwood Plywood and Veneer
Association
P.O. Box 2789
1825 Michael Faraday Drive
Reston, VA 22090-5350
(703) 435-2900

Lead Industries Association (LIA)
295 Madison Avenue, 19th Floor
New York, NY 10017
(212) 578-4750

Manufactured Housing Institute (MHI)
1745 Jefferson Davis Highway, Suite 511
Arlington, VA 22202
(703) 979-6620

National Air Filtration Association
(NAFA)
1518 K Street, N.W., Suite 503
Washington, DC 20005
(202) 628-5328

National Association of Home Builders
(NAHB)
Indoor Air Quality Committee
1201 15th Street, N.W.
Washington, DC 20005
(202) 822-0200

National Paint and Coatings Association
1500 Rhode Island Avenue, N.W.
Washington, DC 20005-5597
(202) 462-6272

National Particleboard Association
18928 Premiere Court
Gaithersburg, MD 20879
(301) 670-0604

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

North American Insulation Manufacturers
Association (NAIMA)
44 Canal Center Plaza, Suite 310
Alexandria, VA 22314
(703) 684-0474

Sealant, Waterproofing and Restoration
Institute (SWRI)
3101 Broadway, Suite 585
Kansas City, MO 64111
(816) 561-8230

Swedish National Flooring Trade
Association (GBR)
P. O. Box 4604
S11691 Stockholm
Sweden

Synthetic Organic Chemical
Manufacturers Association
1330 Connecticut Avenue, N.W.,
Suite 300
Washington, DC 20036-1791
(202) 659-0060

K4 Building Service Associations

American Consulting Engineers Council
1015 15th Street, N.W., Suite 802
Washington, DC 20005
(202) 347-7474

Associated Air Balance Council (AABC)
1518 K Street, N.W., Suite 503
Washington, DC 20005
(202) 737-0202

Association of Specialists in Cleaning and
Restoration International
10830 Annapolis Junction Rd., Suite 312
Annapolis Junction, MD 20701
(301) 604-4411

National Air Duct Cleaners Association
(NADCA)
1518 K Street, NW, Suite 503
Washington, DC 20005
(202) 737-2926

National Association of Power Engineers
5693 Colombia Pike, Suite 100
Falls Church, VA 22041
(703) 845-7059

National Energy Management Institute
Sacramento Regional Office
4441 Auburn Boulevard, Suite O
Sacramento, CA 95814
Headquarters:
601 North Fairfax Street, Suite 160
Alexandria, VA 22314

National Environmental Balancing Bureau
1385 Piccard Drive
Rockville, MD 20850
(301) 977-3698

National Lead Abatement Council
(NLAC)
105 Campus Drive
Princeton, NJ 08543
(609) 520-1133

National Pest Control Association
8100 Oak Street
Dunn Loring, VA 20027
(703) 573-8330

National Roofing Contractors Association
O'Hare International Center
10255 W. Higgins Road, Suite 600
Rosemont, IL 60018-5607

Sheet Metal and Air-Conditioning
Contractors National Association
4201 Lafayette Center Drive
Chantilly, VA 22021-1209
(703) 803-2980

U.S. Green Building Council
808 17th St., N.W., Suite 200
Washington, DC 20006
(202) 785-7809

K5 Environmental Health Organizations

American Academy of Allergy and
Immunology
611 East Wells Street
Milwaukee, WI 53202
(414) 272-6071

American Academy of Environmental
Engineers (AAEE)
130 Holiday Court, #100
Annapolis, MD 21401
(301) 261-8958

American Cancer Society (ACS)/
National Headquarters
1599 Clifton Road, N.E.
Atlanta, GA 30329
(404) 320-3333

American College of Allergy and
Immunology
85 W. Algonquin Road, Suite 550
Arlington Heights, IL 60005
(708) 427-1200

American Lung Association
1740 Broadway
New York, NY 10019
(212) 315-8700

American Medical Association
(AMA)/Council On Scientific Affairs
535 North State Street
Chicago, IL 60610
(312) 464-5000

American Public Health Association
(APHA)
1015 15th Street, N.W., 3rd Floor
Washington, DC 20005
(202) 789-5600

Association of State and Territorial Health
Officials (ASTHO)
415 2nd Street, N.E., Suite 200
Washington, DC 20002
(202) 546-5400

Asthma and Allergy Foundation of
America
1125 15th Street, N.W., Suite 502
Washington, DC 20005
(202) 466-7643

Coalition On Smoking and Health (CSH)
1150 Connecticut Avenue, N.W.,
Suite 820
Washington, DC 20036
(202) 452-1184

Environmental Health Network
P. O. Box 1155
Larkspur, CA 94977
(415) 541-5075

National Association of Environmental
Professionals (NAEP)
5165 MacArthur Boulevard, N.W.
Washington, DC 20016
(202) 966-1500

National Center for Environmental Health
Strategies
1100 Rural Avenue
Voorhees, NJ 08043
(609) 429-5358

National Coalition On Indoor Air Quality
(NCIAQ)
1518 K Street, N.W., Suite 503
Washington, DC 20005
(202) 628-5336

National Environmental Development
Association/Total Indoor
Environmental Quality Coalition
(NEDA/TIEQ)
1440 New York Avenue, N.W., Suite 300
Washington, DC 20005
(202) 638-1200

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

National Environmental Health
Association
720 South Colorado Boulevard
South Tower Suite 970
Denver, CO 80222
(303) 756-9090

National Foundation for the Chemically
Hypersensitive
P. O. Box 9
Wrightsville Beach, NC 28480
(919) 270-9441

National Safety Council (NSC)
1121 Spring Lake Drive
Itasca, IL 60143-3201
(708) 285-1121

Occupational Health Foundation
1126 16th Street, N.W.
Washington, DC 20036
(202) 887-1988 or (202) 842-7840

Public Health Foundation
1220 L Street, N.W., Suite 350
Washington, DC 20005
(202) 898-5600

K6 California Air Pollution Control Districts (as of February 1, 1996)

Amador County APCD

500 Argonaut Lane
Jackson, CA 95642-2310
APCO - Noel Bonderson (209) 223-6406
Inspector - Jim Harris
FAX: (209) 223-6260

Bay Area AQMD

939 Ellis Street
San Francisco, CA 94109
APCO - Milton Feldstein (415) 771-6000
749-4970
Deputy APCO - Peter Hess 749-4971
Deputy APCO - Jan Bush 749-4943
Enforcement - Jim Guthrie 749-4792
Fiscal/Admin - Steve Hill 749-4673
Legal - John Powell 749-4920
Permits - John Swanson 749-4735
Tech. Services - Ellen Garvey 749-4730
Plan./Research - Tom Perardi 749-4667
Public Info. - Teresa Lee 749-4900
FAX: (415) 928-8560

Butte County AQMD

9287 Midway, Suite 1A
Durham, CA 95938
APCO - Larry Olde (916) 891-2882
FAX: (916) 891-2878

Calaveras County APCD

Government Center
891 Mountain Ranch Rd.
San Andreas, CA 95249
APCO - Jearl Howard (209) 754-6404
Deputy APCO - Lakhmir Grewal
FAX: (209) 754-6521

Colusa County APCD

100 Sunrise Blvd. #F
Colusa, CA 95932
APCO - Harry Krug (916) 458-0590
FAX: (916) 458-5000

El Dorado County APCD

2850 Fairlane Ct, Bldg. C
Placerville, CA 95667
APCO - Ron Duncan (916) 621-5300
Program Mgr. - Dennis Otani
(916) 621-6662
FAX: (916) 626-7130

Feather River AQMD

938 14th Street
Marysville, CA 95901
APCO - Ken Corbin (916) 634-7659
FAX: (916) 634-7660

Glenn County APCD

P.O. Box 351 (720 N. Colusa St.)
Willows, CA 95988
APCO - Ed Romano (916) 934-6500
Technical - Kevin Tokunaga,
Rick Steward
FAX: (916) 934-6503

Great Basin Unified APCD

157 Short Street, Suite 6
Bishop, CA 93514
APCO - Dr. Ellen Hardebeck (619) 872-8211
Deputy APCO - Duane Ono
FAX: (619) 872-6109

Imperial County APCD

150 South 9th Street
El Centro, CA 92243-2801
AQCO - Stephen Birdsall (619) 339-4314
Deputy AQCO - Jeannette Bryant
(619) 339-4606
Deputy AQCO - Gaspar Torres
FAX: (619) 353-9420

Kern County APCD

2700 "M" Street, Suite 290
Bakersfield, CA 93301
APCO - Thomas Paxson, P.E.
(805) 862-5250
FAX: (805) 862-5251

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

Lake County AQMD

883 Lakeport Blvd.

Lakeport, CA 95453

APCO - Robert L. Reynolds

(707) 263-7000

(707) 263-3225

FAX: (707) 263-0421

Lassen County APCD

175 Russell Avenue

Susanville, CA 96130

APCO - Kenneth R. Smith (916) 251-8110

Ext. 110

FAX: (916) 257-6515

Mariposa County APCD

P.O. Box 2039 (4988 Eleventh St.)

Mariposa, CA 95338

APCO - Ed Johnson (209) 966-5151

FAX: (209) 742-5024

Mendocino County APCD

Courthouse (306 E. Gobi St.)

Ukiah, CA 95482

APCO - David Faulkner (707) 463-4354

FAX: (707) 463-5707

Modoc County APCD

202 West 4th Street

Alturas, CA 96101

APCO - Les Wright (916) 233-6419

Technician - John E. Kelly (916) 667-2713

FAX: (916) 233-5542

Mojave Desert AQMD

15428 Civic Drive, Suite 200

Victorville, CA 92392

APCO - Chuck Fryxell (619) 245-1661

Division Chief - Eldon Heaston

Planning - Christian Ihenacho

Monitoring - Bob Ramirez

Toxics - Vacant

Division Chief - Edlon Heaston (Acting)

Engineering - Chris Collins

Compliance - Dough McCauley

Public Information - Don Blakemore

Administration - Scott Duncan

FAX: (619) 245-2699

Monterey Bay Unified APCD

24580 Silver Cloud Ct.

Monterey, CA 93940

APCO - Doug Quetin (408) 647-9411

District Counsel - David Schott

Engineering - Fred Thoits

Planning/Aid Monitoring - Janet Brennan

Public Affairs Officer - Tom Manheim

Enforcement - Ed Kendig, Esq.

Source Testing - Larry Borelli

Administrative Services - Bill Fergus

FAX: (408) 647-8501

North Coast Unified AQMD

2389 Myrtle Avenue

Eureka, CA 95501

APCO - Wayne Morgan (707) 443-3093

Engineering - Bob Clark

FAX: (707) 443-3099

Northern Sierra AQMD

P.O. Box 2509

200 Litton Dr., Suite 320

Grass Valley, CA 95945

APCO - Rod Hill (916) 274-9360

FAX: (916) 274-7546

Northern Sonoma County APCD

109 North Street

Healdsburg, CA 95448

APCO - Barbara Lee (707) 433-5911

FAX: (707) 433-4823

Placer County APCD

DeWitt Center

11464 "B" Avenue

Auburn, CA 95603

APCO - Richard Johnson (916) 889-7130

FAX: (916) 889-7107

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

Sacramento Metro AQMD

8411 Jackson Rd.

Sacramento, CA 95826

APCO - Norman D. Covell (916) 386-6183

Rules - Nancy Ormandy (916) 386-6606

Field Operations -

Eric Munz (916) 386-6617

Permitting - Bruce Nixon (916) 386-6623

Prog. Coord. -

Brigitte Tollstrup (916) 386-6672

Strategic Planning -

Karen Wilson (916) 386-6667

Public Information -

Kerry Shearer (916) 386-6180

Mobile Sources -

Tim Taylor (916) 386-7042

Special Projects - Vacant

Administration -

Lashelle Carlyse (916) 386-7004

FAX: (916) 386-6650

San Diego County APCD

9150 Chesapeake Drive

San Diego, CA 92123-1096

APCO -

Richard J. Sommerville (619) 694-3300

Secretary -

Nancy Torregrossa (619) 694-3302

Deputy Directors

Richard J. Smith (619) 694-3303

Morris Dye (619) 694-3303

Administrative - Linda Fox (619) 694-3306

Compliance -

Teresa Morris (619) 694-3342

Mon./Tech. Services -

Judith Lake (619) 694-3351

Engineering - Michael Lake (619) 694-3313

Air Resources &

Strategy Development - Vacant

Public Information -

Bob Goggin (619) 694-3332

FAX: (619) 694-2730

San Joaquin Valley Unified APCD

1999 Tuolumne, Ste. 200

Fresno, CA 93721-1638

APCO - David L. Crow (209) 497-1000

Deputy APCO - Mark Boese

Planning - Robert Dowell

Permitting - Sayed Sadredin

Compliance - Bob Kard

District Counsel - Philip M. Jay

Administrative Services - Roger McCoy

Public Information/Education - Josette Bello

FAX: (209) 233-2057

Bakersfield Office (805) 861-3682

2700 M Street, Ste. 275

Bakersfield, CA 93301-2370

FAX: (805) 861-2060

Modesto Office (209) 545-7000

4230 Kiernan Avenue, Ste. 130

Modesto, CA 95356-9321

FAX: (209) 545-8652

San Luis Obispo County APCD

2156 Sierra Way, Suite B

San Luis Obispo, CA 93401

APCO - Robert W. Carr (805) 781-5912

Planning - Larry Allen

Public Information - Kathy Wolff

Engineering - David Dixon

Compliance - Karen Brooks

Monitoring/Technical Services - Paul Allen

Toxics - Tom Roemer

FAX: (805) 781-1035

Santa Barbara County APCD

26 Castilian Dr., Suite B-23

Goleta, CA 93117

APCO - Doug Allard (805) 961-8800

Technology & Env. Assessment - Kathy Milway

Administrative Services - John Nicholas

Engineering - Peter Cantle

Regulatory Compliance - Terry Dressler

FAX: (805) 961-8801

California Department of Health Services

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines

Shasta County AQMD

1640 West Street
Redding, CA 96001
APCO - Michael Kussow (916) 225-5674
FAX: (916) 225-5237

Siskiyou County APCD

525 So. Foothill Drive
Yreka, CA 96097
APCO - James R. Massey (916) 842-8029
Program Manager - Patrick Griffin
FAX: (916) 842-6690

South Coast AQMD

21865 E. Copley Drive
Diamond Bar, CA 91765 (909) 396-2000
Executive Officer - James M. Lents
Stationary Sources Rules & Compliance
P. Leyden, W. Fray
Planning & Technology Advancement
B. Wallerstein
Chief Scientist - Vacant
Public Advisor - La Ronda Bowen
Technical Support Services - Nick Nikkila
Government Affairs/Media - Tom Eichorn
Fiscal - Rick Pearce
Counsel - Peter Greenwald
Chief Prosecutor - Vacant
FAX: (909) 396-3340

Tehama County APCD

P.O. Box 38 (1750 Walnut Street)
Red Bluff, CA 96080
APCO - Heidi W. Hill
Assistant APCO -
Gary Bovee (916) 527-3717
FAX: (916) 529-1049

Tuolumne County APCD

2 South Green Street
Sonora, CA 95370
APCO -
Gerald A. Benincasa (916) 533-5693
Deputy APCO - Mike Waugh
FAX: (209) 533-5520

Ventura County APCD

669 County Square Dr., 2nd Floor
Ventura, CA 93003
APCO -
Richard H. Baldwin (805) 645-1440
Deputy APCO - Bill Mount (805) 645-1430
Enforcement - Keith Duval (805) 645-1410
Eng/Permits - Karl Krause (805) 645-1420
Rule - Mike Villegas (805) 645-1412
Monitoring - Doug Tubbs (805) 645-2809
Planning - Scott Johnson (805) 645-1491
Fiscal - Henry Solis (805) 645-1416
FAX: (805) 645-1444

Yolo/Solano AQMD

1947 Galileo Ct., Ste. 103
Davis, CA 95616
APCO - Ken Selover (916) 757-3675
Compliance -
Annette Carruthers (916) 757-3659
Planning - Carl Vandagriff (916) 757-3668
Engineering -
Steve Speckert (916) 757-3655
Board Clerk -
Eleanora Bailey (916) 757-3657
FAX: (916) 757-3670

K7 California Public Agencies and Organizations That Can Assist People with Indoor Air Quality Concerns

A directory compiled by the California Interagency Working Group on Indoor Air Quality and published by the California Department of Health Services lists names, addresses, telephone numbers, and brief descriptions of California agencies and organizations that can assist people with indoor air quality concerns. The *California Indoor Air Quality Assistance Directory* can be obtained free of charge by writing or calling to the following address:

California Indoor Air Quality Section
Environmental Health Laboratory Branch
Department of Health Services
2151 Berkeley Way, Room 334
Berkeley, CA 94704-1011
(510) 540-2469
Fax: (510) 540-3022
www.cal-iaq.org

A list of private firms that offer indoor air quality services in California is also available free of charge at the above address.

K8 Publications and Written Material on Indoor Air Quality

K8.1 List of USEPA's publications

The following USEPA publication, which is a good reference for building owners and facility managers, is available for purchase:

USEPA. 1991. *Building Air Quality: A Guide for Building Owners and Facility Managers*, United States Environmental Protection Agency, EPA/400/1-91/033, Washington, DC. Available from the United States Printing Office, Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328 (ISBN 0-16-035919-8)

Other publications listed below are available from the USEPA's Indoor Air Quality Information Clearinghouse free of charge from the following address:

Indoor Air Quality Information Clearinghouse
United States Environmental Protection Agency
P.O. Box 37133
Washington, DC 20013-7133
(800) 438-4318 or (202) 484-1307
Fax: (202) 484-1510

List of USEPA's publications:

USEPA. 1990. *Ventilation and Air Quality in Offices*, Fact Sheet No. 3, United States Environmental Protection Agency, 402-F-94-003, Washington, DC.

USEPA. 1991. *Indoor Air Facts: Sick Building Syndrome*, Fact Sheet No. 4 (revised), United States Environmental Protection Agency, 402-F-94-004, Washington, DC.

USEPA. 1992. *Carpet and Indoor Air Quality*, Fact Sheet, United States Environmental Protection Agency, Washington, DC.

USEPA. 1993. *The Inside Story: A Guide to Indoor Air Quality*, United States Environmental Protection Agency, EPA 402-K-93-007, Washington, DC.

USEPA. 1993. *Targeting Indoor Air Pollution: EPA's Approach and Progress*, United States Environmental Protection Agency, EPA 400-R-92-012, Washington, DC.

USEPA. 1993. *Current Federal Indoor Air Quality Activities*, United States Environmental Protection Agency, EPA 402/K-93/033, Washington, DC.

K8.2 List of National Institute of Standards and Technology Publications:

Dols, W.S.; Persily, A.K.; and Nabinger, S.J. 1995. *Indoor Air Quality Commissioning of a New Office Building*. Gaithersburg, MD: National Institute of Standards & Technology, NISTIR 5586.

K8.3 List of the CARB's publications:

1. Indoor Air Quality-Related:

CARB. 1991. *Indoor Air Quality Guideline No. 1: Formaldehyde in the Home*. Sacramento, California: California Air Resources Board, Research Division.

2. Architectural Coatings-Related:

- a) ARB-CAPCOA. 1989. *ARB-CAPCOA Suggested Control Measure For Architectural Coatings - Technical Support Document*. Sacramento, California: California Air Resources Board (Stationary Source Division) and California Air Pollution Control Officers Association. July, 1989.

This document recommends limits for VOCs which may be adopted by APCDs and AQMDs. The VOC limits are presented by different categories of architectural coatings. The document includes new and revised definitions of categories of architectural coatings.

- b) CARB. 1994a. *Summary of California's Coating Rules by Air Pollution Control Districts and Air Quality Management Districts*. Sacramento, California: California Air Resources Board, Stationary Source Division, Solvents Control Section. March, 1994.

This document presents descriptions of different coating rules, and indicates the air pollution control districts/air quality management districts in which rules have been adopted. This document does not present specific VOC limits.

- c) CARB 1994b. *Survey of Emissions from Solvent Use. Volume 1: Aerosol Paints. Volume 2: Architectural Coatings*. Contract No. A132-086, Final Report to ARB submitted by Battelle. Sacramento, California: Air Resources Board. September, 1994.

Volume 1: Aerosol Paints

This volume presents results of a survey conducted by ARB of companies that sold aerosol coating products in California. (Note that the survey data were analyzed by Battelle.) The

report presents statistics on sales of aerosol paints, VOC content (percent by weight) and estimated VOC emissions by coating category. It also presents a summary of the BAAQMD rule (Regulation 8, Rule 49, adopted in 1990) that regulates VOC content in hand-held aerosol paint products, with a copy of the BAAQMD rule included in the appendices.

Volume 2: Architectural Coatings

This volume presents results from a survey of architectural coatings manufacturers who sold architectural and industrial maintenance coatings in California in 1990. This report includes sales in gallons of different architectural coatings by type, estimated emissions of VOCs by coating type, estimates of emission reductions due to 1989 ARB-CAPCOA Suggested Control Measure 1992 standards relative to the 1990 emissions, and a comparison of 1990 survey results with earlier CARB surveys.

3. Aerosol Coating Products-Related:

- a) CARB. 1995a. *Initial Statement of Reasons for a Proposed Statewide Regulation to Reduce Volatile Organic Compound Emissions from Aerosol Coating Products and Amendments to the Alternative Control Plan for Consumer Products*. Sacramento, California: California Air Resources Board, Solvents Control Section, Stationary Source Division. January, 1995.

This document presents the CARB staff's proposed regulation (adopted 1/8/96) to reduce emissions of VOCs from aerosol paints. It also presents the technical support document prepared by the CARB staff, which includes a summary of the legislation, technical background information, environmental and economic impacts, and VOC emissions by product category.

- b) CARB. 1995b. "Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products." *Health and Safety Code*, Sections 39002, 39600, and 40000, and 41712.

This regulation presents VOC limits by aerosol paint product categories, and regulatory definitions.

4. Consumer Products-Related:

- a) CARB. 1993a. *Regulation for Reducing Volatile Organic Compound Emissions From Consumer Products And Antiperspirants And Deodorants*. Sacramento, California: State of California, Air Resources Board. Effective: January 6, 1993.

This document presents two regulations, Article 1 (Antiperspirants and Deodorants, Sections 94500-94506.5) and Article 2 (Consumer Products, Sections 94507-94517) of Title 17, California Code of Regulations, Division 3, Chapter 1, Subchapter 8.5. These regulations include a table of standards specifying VOC limits (percent by weight) for different product categories; this table also presents the dates these limits are effective.

- b) CARB. 1994c. *Proposed Alternative Control Plan Regulation for Consumer Products, Staff Report*. Sacramento, California: California Air Resources Board, Stationary Source Division. August, 1994.

This document presents a detailed description of the Alternative Control Plan (ACP), a voluntary program which enlists manufacturers to limit VOCs in consumer products.

K9 Irritation/Toxicity Information Sources

The following are sources of information on chemical irritants and toxicants.

1. Integrated Risk Information System (IRIS): on line.
2. Health Effects Assessment Sensory Table (HEAST): available from the National Technical Information Service (NTIS).
3. Registry of Toxic Effects of Chemical Substances (RTECS): available from NIOSH.
4. Sax and Lewis (1989 or most recent edition) Dangerous Properties of Industrial Materials: available from Van Nostrand Reinhold publishing company.
5. Toxicological profiles of approximately 120 hazardous substances found at National Priorities List (NPL) sites. Toxicological profiles are developed by the Agency for Toxic Substances and Disease Registry (ATSDR) and are available from NTIS, 5285 Prt Royal Road, Springfield, Virginia 22161 (Phone: 800-553-6847 or 703-487-4650.) A number of draft toxicological profiles are available for public comment from: Division of Toxicology, ATSDR, 1600 Clifton Road NE, Mail Stop E-29, Atlanta, Georgia 30333.
6. Hazardous Substance Data Bank (HSDB): available from the National Library of Medicine.